EDGEWOOD

CHEMICAL BIOLOGICAL CENTER

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

ECBC-TR-522

VALIDATION OF FMTV MODULAR VHP/mVHP SYSTEM AND FUMIGATION DECONTAMINATION PROCESS IN A C-141B STARLIFTER AIRCRAFT

Mark D. Brickhouse
Teri A. Lalain
Jerry W. Pfarr
Brian K. MacIver

RESEARCH AND TECHNOLOGY DIRECTORATE

John P. Lloyd
James E. Flowers

20th SUPPORT COMMAND (CBRNE)

Brent A. Mantooth
Zach B. Zander
David C. Stark
Matthew J. Shue

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
Abingdon, MD 21009

Diane L. Dutt

MITRETEK SYSTEMS, INC.
Falls Church, VA 22042

August 2007

ABERDEEN PROVING GROUND, MD 21010-5424

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
XX-08-2007	Final	Feb 2006 - Mar 2006

4. TITLE AND SUBTITLE
Validation of FMTV Modular VHP/mVHP System and Fumigation Decontamination Process in a C-141B Starlifter Aircraft

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Brickhouse, Mark D.; Lalain, Teri A.; Pfarr, Jerry W.; MacIver, Brian K. (ECBC); Lloyd, John P.; Flowers, James E. (CBRNE); Mantooth, Brent A.; Zander, Zach B.; Stark, David C.; Shue, Matthew J. (SAIC); and Dutt, Diane L. (MTS)

5d. PROJECT NUMBER
None

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-RT-PD, APG, MD 21010-5424
20th Support Command (CBRNE), APG, MD 21010
SAIC, 3465A Box Hill Corporate Drive, Abingdon, MD 21009
MTS, Falls Church, VA 22042

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TR-522

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT:
The C141 test was designed to further demonstrate that decontaminating substrates contaminated with chemical and biological warfare threat materials, while maintaining a near constant hydrogen peroxide/ammonia fumigant concentration (500 ppm/30 ppm) and varying exposure durations during separately timed runs, was reproducible. The test was also designed to demonstrate the ability to consistently achieve effective kills on materials contaminated with biological and chemical challenges set by the Joint Portable Interior Decontamination Program Operational Requirements Document. In addition, the next generation delivery system for vaporous hydrogen peroxide (VHP)/modified VHP (mVHP) (using a Medium Tactical Vehicle) was effective in performing the biological and chemical decontamination of a volume of 13,000 ft^3. The technical results are presented in this report.

15. SUBJECT TERMS

VHP/mVHP	C-141B Starlifter Aircraft	BIs	*Geobacillus stearothermophilus*
mVHP System	Vaporizer Modules	Coupons	HD
Ammonia	CARC	CEPS	

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Sandra J. Johnson
					19b. TELEPHONE NUMBER *(include area code)*
U	U	U	UL	122	(410) 436-2914

Blank

PREFACE

The STERIS Vaporous Hydrogen Peroxide (VHP®) technology has been used for more than a decade to sterilize pharmaceutical processing equipment and clean rooms. In Oct. 2001, the VHP technology was adapted to decontaminate two anthrax-contaminated buildings in the Washington, D.C. area. In 2002, Steris subsidiary Strategic Technology Enterprises (STE) and the Edgewood Chemical Biological Center (ECBC) began the process to co-develop a modified VHP (mVHP) capable of biological and chemical decontamination. Over the past few years, the mVHP fumigant has been significantly improved for the decontamination of materials contaminated with chemical agents VX, GD and HD. During this time, the mVHP system was also improved to enable better distribution and higher concentrations. The mVHP technology was widely scalable and adaptable to accommodate a wide range of applications such as buildings, aircraft and sensitive equipment. Many programs were executed during this time to demonstrate application and determine agent efficacy. Several demonstrations were successfully completed showing large-venue applications and efficacy against agent surrogates. The biological chambers and a bio safety level three (BSL-3) laboratory tests were to determine the decontamination efficacy against biological agent and surrogate on operationally relevant materials. The chemical chambers work was to determine the decontamination efficacy against chemical agents HD, VX, TGD and GD on operationally relevant materials. This report documents the most recent C141 aircraft demonstration. The work was completed under Contract Order Number W9115R-04-C-0074, "Demonstration of the decontamination of a C141 in Evaluation of mVHP Aircraft Materials Components and Equipment." The work discussed in this report was conducted from February to March 2006.

The use of either trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. Manufacturer names and model numbers were provided for completeness. This technical report may not be cited for purposes of advertisement.

This report has been approved for public release. Registered users should request additional copies from the Defense Technical Information Center; unregistered users should direct such requests to the National Technical Information Service.

Acknowledgments

A program cannot be successfully completed without the contributions of a good team of people. The authors thank the following individuals for their hard work and assistance with the execution of this technical program.

- Thanks to Beth DeRego for assisting with the document proofreading.
- Thanks to Dr. Steve DiVarco for writing the IH plan and making the arrangements for testing at Davis-Mothan AFB, Tucson, AZ.
- Thanks to the staff at Davis-Monthan for hosting us and allowing us to complete the test program at the facility.

Blank

CONTENTS

APPENDIXES

FIGURES

TABLES

Blank

VALIDATION OF FMTV MODULAR VHP/mVHP SYSTEM AND FUMIGATION DECONTAMINATION PROCESS OF A C-141B STARLIFTER AIRCRAFT

1. INTRODUCTION

The STERIS Vaporous Hydrogen Peroxide (VHP®) technology has been used for more than a decade to sterilize pharmaceutical processing equipment and clean rooms.[1,2] In Oct. 2001, the VHP technology was adapted to decontaminate two anthrax-contaminated buildings in the Washington, D.C. area. In 2002, STERIS Corporation, Inc. subsidiary, Strategic Technology Enterprises (STE), and the Edgewood Chemical Biological Center (ECBC) began the process to co-develop a modified VHP (mVHP) capable of biological and chemical decontamination. Over the past few years, the mVHP fumigant has been significantly improved for the decontamination of materials contaminated with chemical agents VX, GD and HD.[3] The mVHP technology was developed and patented through a Cooperative Research and Development Agreement (CRADA) between ECBC and STE. During this time, the mVHP system was also improved to enable better distribution and higher concentrations. The mVHP technology was scalable and adaptable to accommodate wide range of applications such as buildings, aircraft and sensitive equipment. Many programs were executed during this time to demonstrate application and determine agent efficacy.[4] The modular mVHP™ system was successfully demonstrated in a former office building decontamination tests at the Aberdeen Proving Grounds (APG) in Maryland and C-141B aircraft decontamination tests at Davis-Monthan AFB, Tucson, AZ.[5-6] The biological chambers and BSL-3 laboratory work was performed to determine the decontamination efficacy against biological agent and surrogate on operationally relevant materials. The chemical chambers work was performed to determine the decontamination efficacy against chemical agents HD, VX, TGD and GD on operationally relevant materials.[7] The VHP/mVHP decontamination tests and demonstrations were part of a congressionally funded joint venture between ECBC and STE.

The primary objective of this test was to demonstrate the mVHP system ability to decontaminate representative operationally relevant materials for biological- and chemical-warfare agent surrogate contamination in the cargo bay of a C-141B Starlifter aircraft. The decontamination efficacy was compared to the Key Performance Parameters (KPPs) stated in the Operational Requirements Document (ORD) for Joint Platform Interior Decontamination (JPID).[8] The tests were performed between February and March 2006 at the Davis-Monthan AFB, Tucson, AZ.

1.1 Summary of Conclusions.

The purpose was to demonstrate the mVHP system ability to decontaminate representative operationally relevant materials for biological- and chemical-warfare agent surrogate contamination in the cargo bay of a C-141B Starlifter aircraft. The summary of conclusions was provided in the following bulleted list.

- The mVHP system demonstrated the ability to reach 500-ppm hydrogen peroxide and a 30-ppm ammonia mVHP concentration in a simulated operational environment (C141).

- The mVHP system demonstrated the ability to reach process conditions in a simulated operational environment. (Section 4.1.2)

    - The mVHP system was able to effectively warm the cargo bay interior to achieve treatment temperatures in the range of 30 °C (86 °F) to 41 °C (106 °F).

    - The mVHP system demonstrated the ability to reach target process conditions when the exterior humidity was high.

- Some biological control coupon recoveries were below the target 1 x 10^6 cfu/coupon load.

    - The starting challenge of 1.5 x 10^6 cfu/coupon (5.9 x 10^9 cfu/m^2) was greater than the required JPID starting challenge of 1.5 x 10^8 cfu/m^2.

    - The glass samples showed a 1.5 x 10^6 cfu/coupon recovery.

    - The CARC-coated samples showed a 2.6 x 10^5 cfu/coupon recovery.

    - The aluminum samples showed a 2.3 x 10^4 cfu/coupon recovery.

- Biological surrogate results compared to control samples showed:

    - A 6-log reduction in viable spores can be achieved on glass in a 4-5-hr treatment, which was a JPID ORD-equivalent reduction in viable spores.

    - A minimum 5-log reduction in viable spores can be achieved on CARC-coated metal in a 4-5-hr treatment.

    - A minimum 4-log reduction in viable spores can be achieved on aluminum in a 4-5-hr treatment.

    - If the control recoveries were truly 6-log, then all three materials would show a JPID ORD-equivalent reduction in viable spores in a 4-5-hr treatment.

- The Biological Indicator (BI) results show:

    - Most BIs were rendered nonviable in a 4-5-hr mVHP treatment.

- Initial 2-3-hr tests showed increased number of survivors; however, a 2-3 test operation with 50% operating vaporizers was not optimal.

- The initial 2-3-hr tests showed a different between Apex and Steris BIs. Laboratory studies, however, showed that a minimum 40-min exposure was achieved in the laboratory chamber (D-box), the response was the same. The presence of survivors during the early test was attributed to less than optimal test conditions (i.e., 50% of the generators running).

- The HD-simulant CEPS results show:

  - Vapor levels below the JPID threshold and objective limit of 0.0058 mg/m^{3}and 0.003 mg/m^3, respectively.

  - Remaining CEPS post-treatment was greater than the JPID ORD threshold contact exposure level for blister-H (<3.0 mg/m^2) except for the March 7th test, which was below detection limits and shows the potential to meet ORD.

  - Test data is consistent that with longer treatment times the potential to meet ORD with the system evaluated exists.

  - The results show a reduction in HD-simulant concentration with the potential to meet JPID ORD requirements.

  - Pending a rigorous correlation study, CEPS has been observed to be more resistant to VHP than HD.

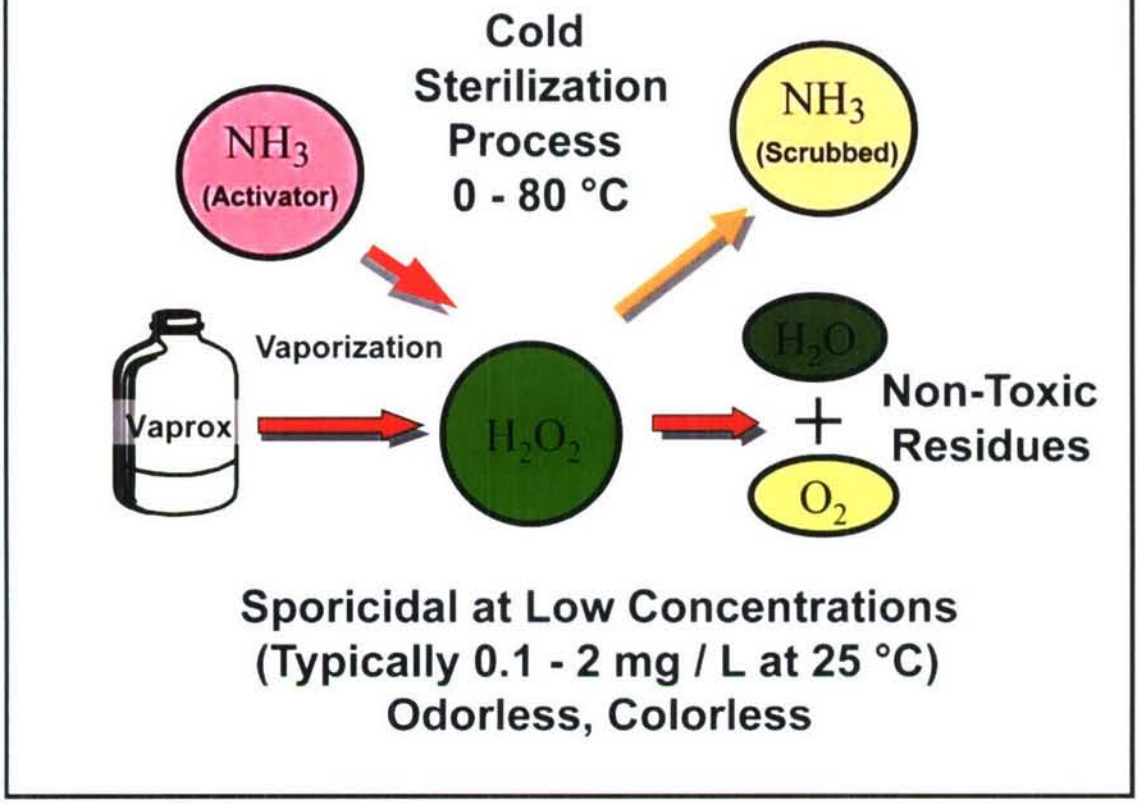
1.2 mVHP® Decontamination Process.

The mVHP is a broad spectrum decontaminant composed of vaporous hydrogen peroxide and a small amount of ammonia gas used within a specified set of conditions. The mVHP decontamination process evaluated was the combination of the patented mVHP decontaminant and decontamination operating conditions.[9,10]

The mVHP decontamination process has been shown effective at atmospheric pressure and at ambient temperatures. The process was completely vapor phase hydrogen peroxide and ammonia. Hydrogen peroxide vapor readily forms hydroxyl free radicals that have been found to react with various micromolecules. VHP rapidly decomposes into two environmentally benign products: oxygen and water vapor (Figure 1.2.1). Metal oxide catalysts were used for large-scale, one-through processes requiring more rapid decomposition on the exhaust stream. The current processes uses up to 30 ppm of ammonia, which was below the Permissible Exposure Limit (PEL) of 50 ppm. Unreacted ammonia was scrubbed out of the

exhaust air through an appropriate filter. The large systems monitor the exhaust for both ammonia and hydrogen peroxide to ensure no fumigant post the filter bed.

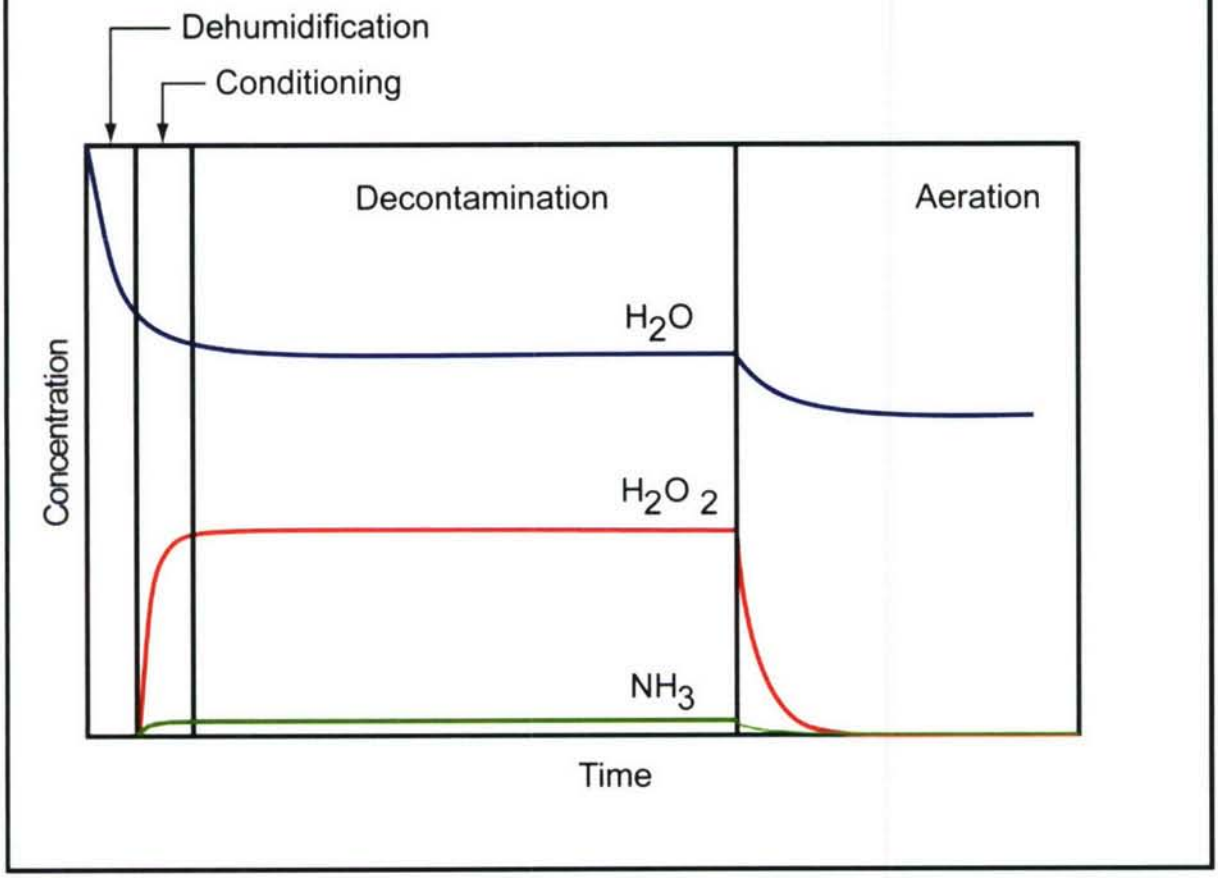
Figure 1.2.1: mVHP® Decontamination Chemistry



Since mVHP was a vapor technique, the primary requirement for decontamination was an enclosure. The technology was versatile - adaptable to enclosures ranging from defined boxes (e.g., SED), to vehicle and building interiors, to tents.[4-7,11,13,14]

Decontamination of an interior/enclosed space using the modular mVHP system was a four-phase process involving preparation of the interior air (dehumidification), achieving a steady state decontaminant level (conditioning), performing the decontamination, and then aerating the space for safe entry (Figure 1.2.2).

Figure 1.2.2: mVHP® Decontamination Cycle



Dehumidification: Hydrogen peroxide vapor can co-condense with water vapor producing an undesired condensate high in hydrogen peroxide. If ambient conditions were likely to permit condensation – high humidity and/or cold temperatures, – this can be prevented by circulating dry, heated air through the interior prior to injection of the hydrogen peroxide vapor. The target humidity level was determined by the concentration of vapor to be injected and the desired steady state concentration for the decontamination. The lower relative humidity (RH) permits a higher concentration of hydrogen peroxide without reaching a saturation point.

Conditioning: During the conditioning phase, injection of ammonia and hydrogen peroxide vapor was initiated. Injection rates were selected to rapidly raise the concentrations to the desired set point without condensation. Internal sensors measure and report the ammonia and hydrogen peroxide concentrations to the control system. When the concentrations reach the set point values, the ammonia and hydrogen peroxide injection rates were lowered to maintain the set-point concentrations. Once all the interior monitors reach or exceed the set point concentration, the system proceeds to the next phase.

Decontamination: Decontamination was timed-phase dependent on the hydrogen peroxide vapor concentration, ammonia vapor concentration and temperature. A decontamination timer counts down from the preset decontamination time. If the concentrations or temperature values fall below the set point, the timer stops. This ensures that during the decontamination phase, the

interior space was exposed to at least the minimum decontamination conditions for the desired exposure time.

Aeration: After completion of the decontamination phase, the system stops injection of hydrogen peroxide and ammonia and introduces only dried air into the building. The dried air displaces the hydrogen peroxide and ammonia. The hydrogen peroxide and ammonia were removed by the exhaust system. Samples were drawn and tested from the exhaust system upstream of the catalyst destroyer. When the measurements were below the ammonia and hydrogen peroxide PELs, the user terminates the aeration process.

2. METHODS AND PROCEDURES

2.1 Family of Medium Tactical Vehicles-Based (FMTV) System.

Steris provided the FMTV for testing at Davis-Monthan AFB. Permanent components of the FMTV include an electrical generator, a power distribution panel, an exhaust system, a heat exchanger, an air compressor and a central control panel (Figure 2.1). Permanent components of the FMTV trailer include a dehumidifier/condenser, and an air handling unit. The trailer can also carry ten modular vaporizer units, each rated to 100 cfm, one large vaporizer unit, rated to 1000 cfm, 38 distribution fans, and sufficient ducting. As a complete package, the FMTV system can provide up 100,000 ft^3 of decontamination capacity.

Figure 2.1: FMTV System

2.2 Site and Aircraft Preparation.

The C-141B Starlifter, designed for long-range troop and cargo airlift, has a cargo length of 168 ft 4 in, a height of 39 ft 3 in, and a wingspan of 160 ft. The cargo load capacity was rated at 6,370 ft^3, but for decontamination purposes, the total cargo area volume was taken as approximately 13,000 ft^3 of air (Figure 2.2). The cargo area was cleared of excess debris for equipment placement. The clam shell-rear cargo hatch and the port side rear access hatch were sealed on the exterior with tape. The Medium Tactical Vehicle (MTV) and modular mVHP system were positioned just behind the port wing.

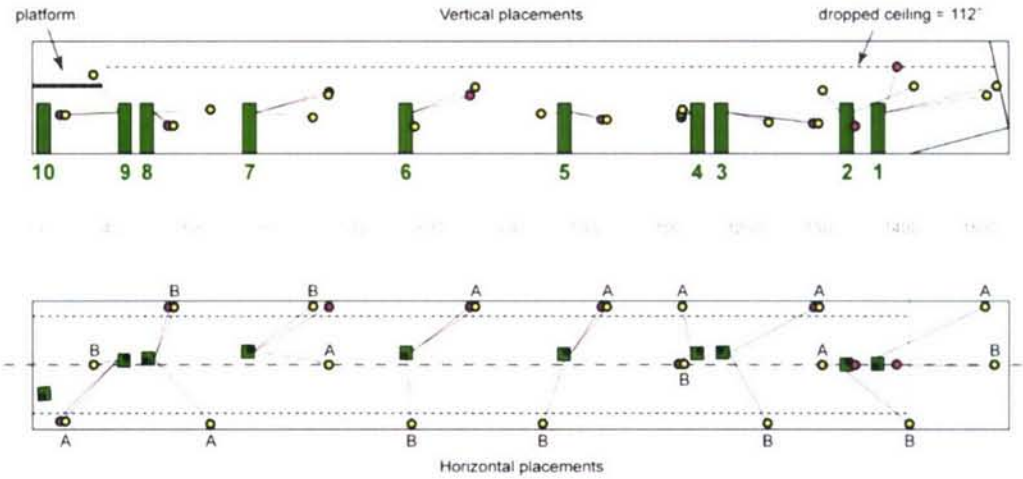
Figure 2.2: C141 Aircraft

2.3 Fan, Vaporizer and Sensor Placements.

To determine placements for fans required to optimize vapor distribution throughout the cargo hold, a Computational Flow Dynamics (CFD) model was developed. The CFD study was documented in the 2005 report.[5] Using the CFD findings, fans and vaporizers were distributed throughout the C-141 cargo area (Table 2.3, Figure 2.3).

Figure 2.3 shows the general locations of each vaporizer (denoted by a green square/rectangle), each hydrogen peroxide concentration sensor (denoted by a yellow dot), and each ammonia concentration sensor (denoted by a blue dot). The locations of the vaporizers and sensors were summarized in Figure 2.3. Each vaporizer module contained one Vaprox® (35% hydrogen peroxide) 5-gallon container. The flow of Vaprox® through the vaporizer nozzles was controlled to deliver the target VHP concentration for the run. During runs employing mVHP, ammonia was injected into the process air as it left the air handling unit on the MTV truck. Note that vaporizer 10 provided VHP/mVHP to the cockpit only. The fans were placed in two rows down the cargo bay (Table 2.3). Temperature and RH probes were placed throughout the interior space and provided real-time feedback to the central control system.

Figure 2.3: Generator and Sensor Placements



Vaporizer Locations

Vaporizer Number	Distance from cockpit (inches)	Approximate Lateral Position	Vaporizer Number	Distance from cockpit (inches)	Approximate Lateral Position
1	1370	Center	6	770	Starboard of Center
2	1330	Center	7	570	Starboard of Center
3	1170	Starboard of Center	8	440	Starboard of Center
4	1140	Starboard of Center	9	410	Starboard of Center
5	970	Starboard of Center	10	0	Center

Sensor Locations

Sensor Number (A/B H2O2, M NH3)	Distance from cockpit (inches)	Approximate Lateral Position	Sensor Number (A/B H2O2, M NH3)	Distance from cockpit (inches)	Approximate Lateral Position
1A	1506	Startboard	6A	860	Starboard
1B	1518	Center	6B	780	Port
1M	1390	Center	6M	860	Starboard
2A	1298	Center	7A	670	Center
2B	1414	Port	7B	650	Starboard
2M	1340	Center	7M	670	Starboard
3A	1290	Startboard	8A	520	Port
3B	1230	Port	8B	470	Starboard
3M	1290	Startboard	8M	470	Starboard
4A	1120	Startboard	9A	330	Port
4B	1118	Center	9B	370	Center
4M	1118	Center	9M	330	Port
5A	1020	Startboard	10A	Cockpit	Center above console
5B	940	Port	10B	Cockpit	Center on console
5M	1020	Startboard	10M	Cockpit	Center above console

Table 2.3: Fan Locations					
Fan Number	Distance from cockpit (inches)	Approximate Lateral Position	Fan Number	Distance from cockpit (inches)	Approximate Lateral Position
1	Rear	Center facing port	11	790	Port
2	1410	Starboard	12	770	Starboard
3	1370	Port	13	580	Port
4	1310	Starboard	14	570	Starboard
5	1160	Starboard	15	450	Port
6	1160	Port	16	440	Starboard
7	1080	Port	17	330	Port facing forward
8	1070	Starboard	18	330	Starboard
9	990	Port	19	Cockpit	Center facing forward
10	970	Starboard	20	Cockpit	Center facing starboard

2.4 Ducting and Air Handling System.

Flexible ducting was used to introduce fresh vapor into and remove spent vapor from the aircraft. The air handling system maintained a forced circulation blower. An in-line chiller unit provided relatively dry air into the process air. On the aircraft end of the line, an anemometer provided pressure feedback information to the central control systems. In the event the exhaust system was unable to maintain negative pressure inside the enclosure, the anemometer signaled an alarm, which sent the system into aeration.

As spent exhaust vapor exited the system, it passed through a large particle filter, a High Efficiency Particulate Air (HEPA) filter for microbial retention, a palladium/platinum catalytic converter to reduce hydrogen peroxide to water and oxygen, and a carbon filter to scrub ammonia. Greater detail about delivery and exhaust systems was documented in the 2005 C141 demonstration report.[5]

2.5 Test Materials.

The Steris C141 mVHP evaluation materials were glass, CARC-painted aluminum and bare aluminum. The biological coupons were 1.3 cm squares. The chemical coupons were 2-in. disks. The glass coupons were ordered pre-cut from McMaster-Carr. All other coupons were cut from stock material. Uniformity was assured by obtaining a large enough quantity of material that multiple test samples were obtained with uniform characteristics (e.g., test coupons will all be cut from the interior rather than the edge of a large piece of material). A test plan was not created for testing, so it was uncertain if the chemical simulant coupons were cleaned prior to testing. The biological test coupons were sterilized prior to use. The coupon preparation information including material vendors and descriptions was provided in Appendix A.

2.6 Mobile Laboratory.

The 20th Support Command was contracted by ECBC/RDECOM, Decontamination Team to provide Chemical analysis, Chemical Laboratory Platform and Biological support and Biology Laboratory Platform for remote analysis. The Mobile Laboratory of the 20th Support Command (Biological system) was deployed and supported the testing and analysis of this equipment. Their role was to test and evaluate the ability of the system to effectively decontaminate a chemical simulant, as well as provide mobile laboratory platforms and laboratory support for biological and chemical analysis. The mobile laboratory comes equipped with a 20-kW on-board diesel generator, a sample refrigerator/freezer, a Class 2BII bio-safety cabinet, a Class 3 glove box, and a climate controllable environment. On-board systems aid in chemical and biological detection capabilities.

2.7 Decontamination Efficacy Targets.

The determination of decontamination efficacy was measured by quantifying the amount of agent (or surrogate) remaining after a decontamination process and comparing to the agent (or surrogate) starting amount. The decontamination efficacy value can typically be expressed in terms of the percent agent (or surrogate) reduction resulting from the decontamination process. The mVHP technology study has evaluated the potential application of the technology to interior decontamination. In May 2005, the Joint Platform Interior Decontamination (JPID) Operational Requirements Document (ORD) was issued specifying threshold and objective key performance parameters (KPP) for thorough decontamination efficacy for chemical vapor- and contact-hazards, and biological agent residual levels.[8,12] In spring 2005, the development of the SED prototype added the evaluation of the technology for the potential application to sensitive equipment. The potential application to sensitive equipment falls under the ORD for the Joint Service Sensitive Equipment Decontamination (JSSED) program Joint Service Interior Decontamination (JSID) document. The JSSED ORD document also specifies threshold and objective KPPs for thorough decontamination efficacy for chemical vapor- and contact-hazards and biological agent residual levels.[11] The JPID and JSSED ORD KPP values were listed in Table 2.7. The evaluation results for this test were only applicable to the JPID ORD KPP values.

2.8 Biological Agent Surrogate.

The selection of an appropriate simulant for biological warfare agent decontamination can be strongly influenced by the active component of the decontaminant to be used. A suitable simulant for the mVHP evaluation should react similar to *Bacillus anthracis*. In addition, the simulant should be more conservative than the actual agent. The simulant should be rendered non-viable in either the same time or longer than the actual agent. The same- or delayed-time effect would enable that the determined simulant decontamination cycle times were more than sufficient for the actual agent decontamination. *Geobacillus stearothermophilus* has been identified as a suitable surrogate for *B. anthracis* for mVHP evaluations.

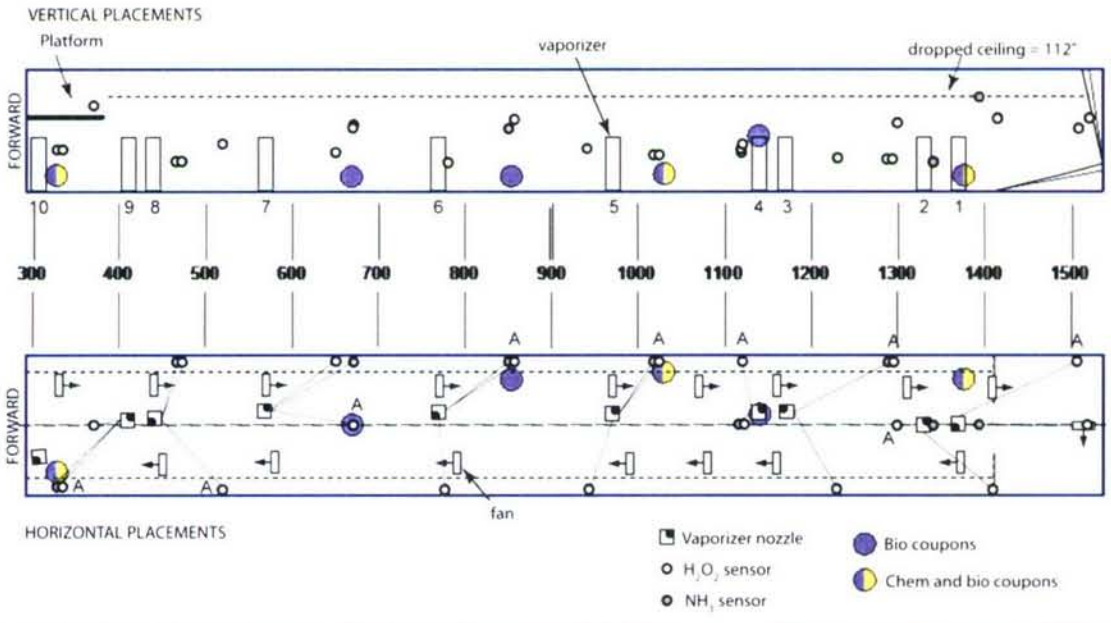
Table 2.7: Operational Requirements Document (ORD) Key Performance Parameters (KPP)				
VAPOR HAZARD	**Starting Challenge**	**Nerve - G**	**Nerve - V**	**Blister - H**
JPID Threshold Vapor Level	1 g/m^2	< 0.00087 mg/m^3	< 0.000036 mg/m^3	< 0.0058 mg/m^3
JPID Objective Vapor Level	1 g/m^2	< 0.0002 mg/m^3	< 0.000024 mg/m^3	< 0.003 mg/m^3
JSSED Threshold Vapor Level	10 g/m^2	< 0.1 mg/m^3	< 0.04 mg/m^3	< 0.1 mg/m^3
JSSED Objective Vapor Level	10 g/m^2	< 0.0001 mg/m^3	< 0.00001 mg/m^3	< 0.003 mg/m^3
CONTACT HAZARD	**Starting Challenge**	**Nerve - G**	**Nerve - V**	**Blister - H**
JPID Threshold Exposure Level	1 g/m^2	< 1.7 mg/m^2	< 0.04 mg/m^2	< 3.0 mg/m^2
JPID Objective Exposure Level	1 g/m^2	0.0 mg/m^2	0.00 mg/m^2	0.0 mg/m^2
JSSED Objective Exposure Level	10 g/m^2	< 16.7 mg/m^2	< 0.78 mg/m^2	< 100 mg/m^2
BIOLOGICAL	**Starting Challenge**	**Bacterial Endospores**	**Vegetative Bacteria**	**Viruses**
JPID Threshold Reduction	$1x10^8$ CFU/m^2	< 100 CFU/m^2	< 10 CFU/m^2	< 10 PFU/m^2
JSSED Objective Reduction	Not specified	< 100 CFU/m^2	< 10 CFU/m^2	< 10 PFU/m^2

2.9 Biological Spore Inoculated Test Coupons.

G. stearothermophilus spore stocks were purchased from Apex Laboratories, Apex, NC (ATCC 7953 Lot 302161, Exp. 30 Apr 07, product number LPT-606). Coupons were sterilized in petri dishes with wire mesh screens with all 3 coupons materials in each dish. They were autoclaved for 25 min at 121 °C and 15 psi. Once dishes were cooled, the surface of each coupon was inoculated with 1 x 10^6 spores in water as a 10-µL volume. The spore-inoculated coupons were left in a bio safety level two (BSL-2) hood until they appeared visibly dry prior to testing. Once dry, the Petri dishes with coupons were transferred to Tupperware containers and transported to the test site for experiments. After the exposure, samples were transported back to the laboratory in Tupperware containers. One of each coupon type for each location was aseptically transferred to 5 mL Tryptic Soy Broth (TSB) and incubated at 55 °C. Coupons were observed the following day. If positive growth (turbid broth) was detected, the remaining 3 coupons were processed. Coupons were aseptically placed in 5 mL buffered peptone water with 0.01% Tween 80 and sonicated for 10 min. Following sonication, 10 µl of Antifoam 289 was added and samples were vortexed at maximum speed for 2 min. Samples were then serially diluted in buffered peptone water and pour plated (1 mL per plate) using Tryptic Soy Agar (TSA). Plates were gently swirled in each direction and allowed to solidify in a biosafety cabinet. Once solidified, plates were transferred to a 55 °C incubator overnight. Resultant colonies were enumerated the following day. The biological test coupon locations and descriptions were provided in Table 2.9.1 and Figure 2.9.

Table 2.9.1: Biological Coupon Locations			
Location Number	**Location Description**	**Location Number**	**Location Description**
1	Atop Vaporizer at 1130	5	850 - Starbord Side
2	Starbord Side - 1010 (by port atop Chem table	6	Forward Port Access door - atop chem table
3	Center of aisle - 660	7	Cockpit - atop port flat "table"
4	Starbord side, by rear door, atop chem table		

Figure 2.9: Biological Coupon Locations



2.10 Biological Indicators.

Commercial *G. stearothermophilus* spore biological indicators (BIs) functioned as a confirmatory test for sporicidal effectiveness. The commercial BIs, inoculated to a level of approximately 10^6 colony forming units (CFUs), were purchased from two vendors, Apex (ATCC 12980, Lot H2165 Exp. 31 March 06), Apex (ATCC 12980, Lot H3355 Exp. 31 Jul 06) and STERIS (ATCC 7953, Lot 0306 Exp. 30 Oct 06). *G. stearothermophilus* was specifically selected for testing since it was a spore forming bacterium that has been identified as an

appropriate conservative surrogate for *B. anthracis* with the VHP technology. After exposure, BIs were transported back to laboratory with coupons in Tupperware containers. In the laboratory, BIs were aseptically transferred to 5 mL TSB broth and incubated for 7 days at 55 °C. Samples were checked daily and were considered non-viable after 7 days if no turbidity (growth) was observed. The BI locations were provided in Table 2.10 and Figure 2.10.

2.11 Chemical Agent Surrogate.

2-Chloroethyl phenyl sulfide (CEPS) was selected as the chemical simulant for the C-141B test. In selecting a suitable surrogate, several parameters were taken into account, including reactivity and vapor pressure. CEPS was chosen because it mimics the oxidative conversion of bis-2-chloroethyl sulfide (HD) to the sulfoxide product better than other used surrogates.[15] Yu-Chu Yang, et.al., compared several bivalent sulfides to HD for their oxidation competition rate, the ratio of the sulfoxide oxidation products from an oxidation reaction, and determined CEPS had a competition oxidation rate similar to HD. The vapor pressure for the agent and surrogate were obtained and plotted as a function of vapor pressure (mmHg) versus temperature (1/T) in Figure 2.11. The vapor pressures and boiling points were well documented for HD and the same for CEPS was obtained from Sigma-Aldrich, however, based on only two available data points. The plots indicate, using this limited data, that CEPS has a lower vapor pressure than HD and, therefore, would be more persistent.

The CEPS was purchased from Sigma-Aldrich, lot 05529LB, 98%, and used as received. The purity was not factored into any sample preparation. HD was used in several correlation studies with the CEPS. The HD was purchased from the U.S. Army Edgewood Chemical Biological Center as chemical agent standard analytical reference material (CASARM).

Table 2.10: Biological Indicator Locations

BI Number	Location Description	BI Number	Location Description	BI Number	Location Description	BI Number	Location Description	BI Number	Location Description
1	Galley, port alcove	21	Port - aft bulkhead	41	Starboard - 650, porthole	61	Cockpit - central console, port side electronics	81	On floor, forward side of Generator #1
2	Port - 370, mid-height	22	Near ceiling on aft loading door	42	Starboard - 530, mid-height	62	Cockpit, upper aft wall	82	Port - 490, bottom of step along wall
3	Port - 430, mid-height	23	Starboard - behind sensor, rear	43	Starboard - 460, aft interior panel	63	Cockpit - starboard pilot forward controls, down low	83	Starboard, bottom edge of wall, under open flap of step
4	Port - 530, box behind sensor 2A	24	Starboard, bulkhead, rear	44	Starboard - 450, inside box	64	On Chem table	84	
5	Port - 650, emergency exit porthole	25	Starboard, 4th rib, deployment area, aft surface	45	Starboard - 390, on shelf behind sensor	65	Aft side of gear pin box, forward section	85	Behind lowest step of ladder on forward bulkhead
6	Port - 740, aft on rib #23	26	Starboard, second rib, deployment area	46	Starboard - 370, alcove	66	Starboard - 1220, under step	86	Bottom, aft frame of V7
7	Port - rib, 830	27	Starboard, steel mechanism	47	Starboard - 350, under shelf	67	On Chem table	87	Port - 750, on wall above step
8	Port - 850, indentation	28	Starboard - 1410, mid-height, in fire suppression equipment alcove	48	Forward bulkhead, starboard side	68	1390 - on floor	88	Aft Port deployment area, over bulkhead (???)
9	Port - 950, at horn	29	Starboard - 1400, mid height	49	Starboard - 320, under MGD kit	69	1320 - on floor	89	900 - aft side of hand pump box
10	Port - 1050, mid-height	30	Starboard - 1360, mid-height	50	Forward bulkhead, under loadmaster log	70	1159 - on floor	90	Port - 800, lower edge of step
11	Port - 1050, aft side of rib	31	Starboard - 1310, mid-height	51	deck under steps to cockpit	71	970 - on floor	91	Port - 990, on cap embedded into wall near 4th fan
12	Port - 1080, indent	32	Starboard - 1220, mid-height	52	On V10	72	On Chem table, near port	92	Starboard - 1040, on step
13	Port - 1150, mid-height	33	Cockpit, mid-height, aft wall	53	On V9	73	On Chem table by aft door	93	Starboard - 1110, on pipe
14	Port - 1200, emergency exit #46	34	Starboard - 1100, forward surface of pipe	54	On V7	74	On Chem table	94	Starboard deployment area, alcove forward
15	Port - 1310, mid-height	35	Starboard - 1050, mid-height	55	On V6	75	Hung above platform, port side	95	Ramp, lower edge, forward
16	Port - 1370, mid-height	36	Starboard - 950, mid-height	56	On V5	76	Ceiling, port, 860	96	Front of control cabinet, deployment area
17	Port - 1410, control panel	37	Starboard - 870, mid-height	57	On V4	77	Ceiling, center, 1040	97	Aft, overhead in circle, left side of port circle
18	Prot - aft on rib	38	Starboard, 830, in alcove	58	On V3	78	Ceiling, center, 1260	98	Port deployment area, aft surface inside of hydraulic oil box
19	-	39	Starboard - 750, on oxygen box	59	On V2	79	On platform, overhead, forward section	99	Aft, overhead in circle, forward surface of starboard circle
20	Port - aft locking mechanism - inside open panel	40	Starboard - on oxygen sensor unit	60	On V1	80	On platform, overhead, aft section	100	Starboard engine oil box, deployment area

Figure 2.10: BI Locations

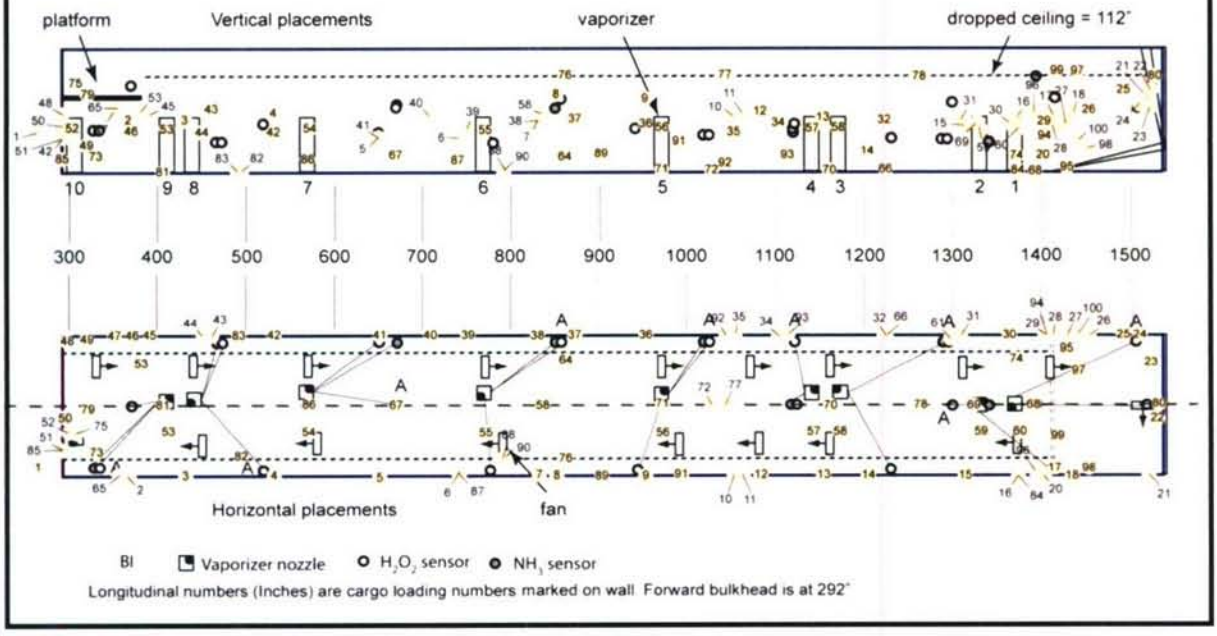
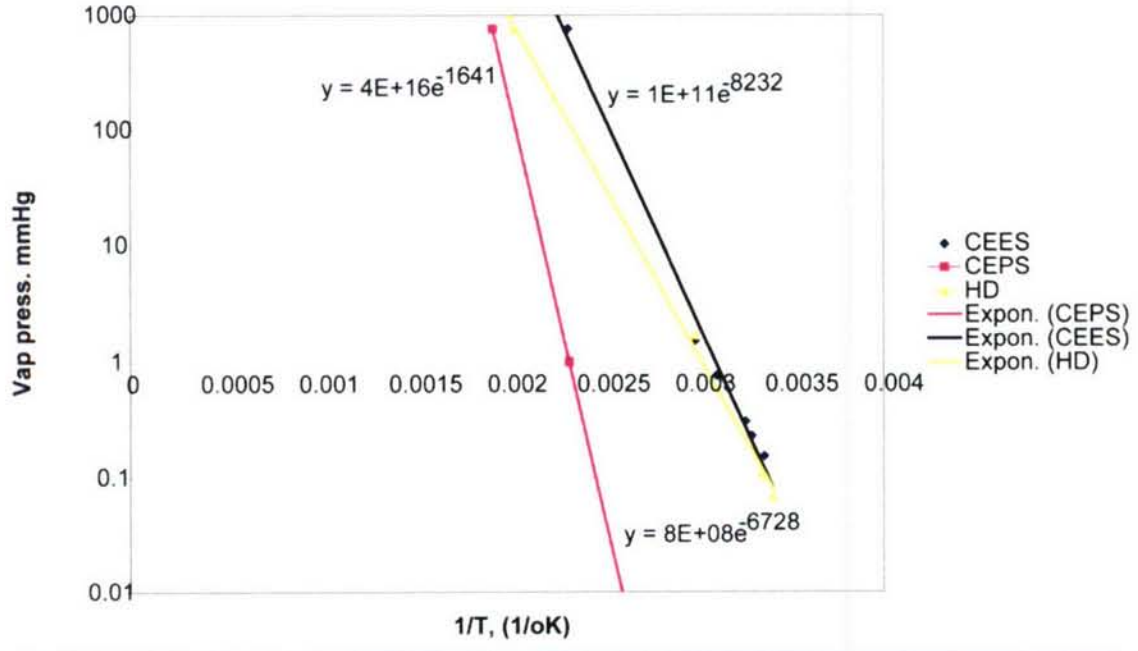


Figure 2.11: Agent and Simulant Vapor Pressure Comparison



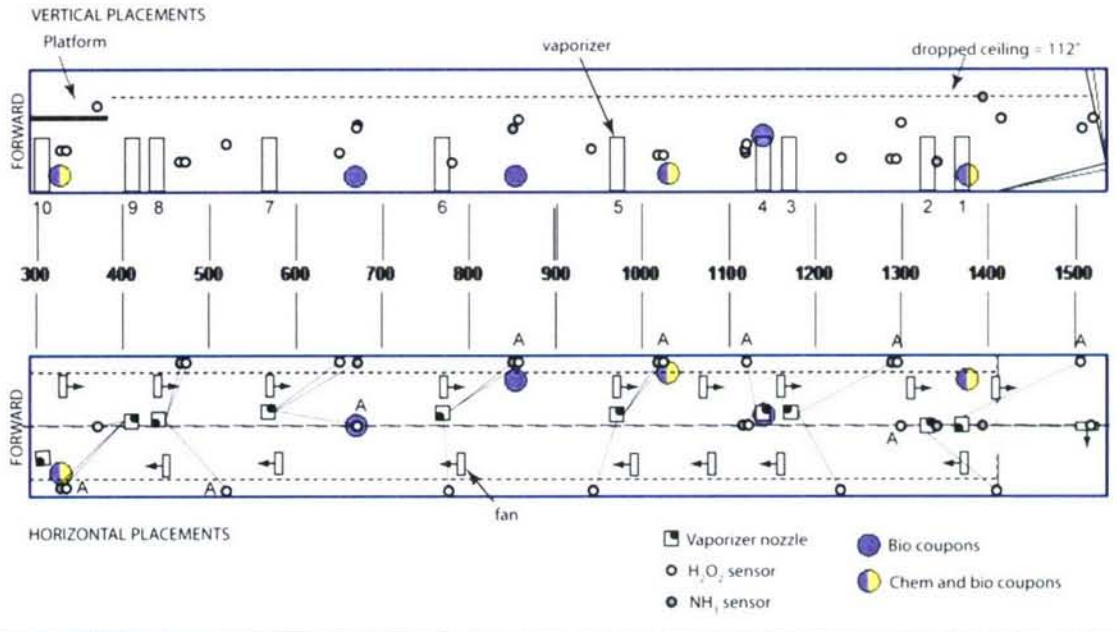
2.12 Chemical Agent Surrogate Contaminated Coupons.

Coupons were contaminated with CEPS to a density of 1 g/m^2 using a Hamilton repeating (syringe) dispenser. The CEPS was applied by pipetting 0.5-µL drops in a uniform repetitive distribution pattern onto the coupon surfaces. Once the final coupon was contaminated, the total were immediately placed in a plastic storage container and sealed to prevent the evaporative loss during transport from the fume hood to the aircraft. A small amount of evaporative loss may have occurred during the contamination period and transport to the aircraft. The time required to contaminate an entire batch of coupons was approximately 7 min. The transportation time from the mobile laboratory, where the coupons were contaminated, to the aircraft took approximately 8 min. Coupons were inserted into the aircraft and the front and rear hatches immediately closed to begin the decontamination process. Samples were retrieved from the aircraft once the decontamination process cycle was complete and the VHP concentration was measured to be below the PEL of 1 ppm. Samples were then place back into the plastic storage containers and returned to the mobile laboratory for processing, again the travel time was 8 min.

Baseline samples to account for evaporative loss during transport and handling were not conducted; therefore, agent simulant loss was not measured or accounted for in the final efficacy analysis.

Sample coupons (Figure 2.12) were placed in three separate locations within the aircraft fuselage: directly adjacent the port forward and starboard rear hatch and starboard amidships (aircraft station 1028). The coupons were placed in a horizontal position resting on a small table approximately 20 cm above the deck.

Figure 2.12: Chemical Coupon Locations



2.13 Contact-Hazard Measurement.

The test coupons were contaminated to a density of 0.82 g/m^2. The CEPS was applied by pipetting 0.5 µL drops in a uniform repetitive distribution pattern onto the coupon surfaces. The coupons were then placed in a plastic storage container and covered to prevent the evaporation of the simulant.

Sample coupons were placed within the fume hood, contaminated side up. A 2-in. diameter piece Dental Dam (natural rubber latex) was applied, covered with standard aluminum foil and weighted with a 1-kg steel 2-in. diameter rod. After 15 min the weight was removed. The latex was placed in 10 mL of chloroform and sealed in a 20-mL scintillation vial. A second piece of latex was applied to the sample coupons and again weighted for an additional 45-min period at which time was extracted into a second scintillation vial with 10 mL of chloroform. The chloroform was purchased from Fisher Scientific (HPLC grade) and the Dental Dam purchased from Henry Schein. Each latex sample was extracted for 15 min at which time an aliquot was removed to a gas chromatography (GC) vial for analysis. The aliquots were stored at 4 °C until analyzed. The GC calibration range was from 1- to 250-ng. The 1-ng standard was equivalent to 20000 ng per coupon, which was equivalent to 10 mg/m^2. Since the JPID ORD was 3 mg/m^2, the calibration range could not measure at the ORD threshold levels. However, when there was no detectable peak, the values were reported as non-detect (ND) and treated as zero.

Contact hazard of CEPS was determined by taking the GC results reported in nanograms per microliter (uL) and converting to mass. The mass was then converted to milligrams and divided by the coupon area in m^2 . The following formula was used to calculate the remaining contamination density: CEPS] mg/m ^{2} = (Mass of CEPS (ng)) (1 x 10-6 (mg/ng))/(Coupon Area (m^2))

2.14 Offgas (Vapor)-Hazard Measurement

Sample coupons were analyzed for CEPS vapor within a confined headspace to determine the effectiveness of the decontamination process as a correlating to safe exposure levels (as defined within the JPID ORD for HD. Vapor cups were fashioned from seamless tin cans with lids (3-in. diameter x 1-in. height). The tin cans were purchased from McMaster-Carr. Two 7/16-in. holes were punched in each lid to accept two stainless steel, ¼-in. fitting, male bulkhead Swagelok® connectors obtained from the Baltimore Valve Company. A ¼-in. Teflon® furrell was inserted into each fitting to accept a depot area air monitoring system (DAAMS) tube at one end of the cup and a charcoal filter at the other. The measured volume of the tin can was approximately 120 cm^3, not taking into consideration the volume displaced by the connector nuts.

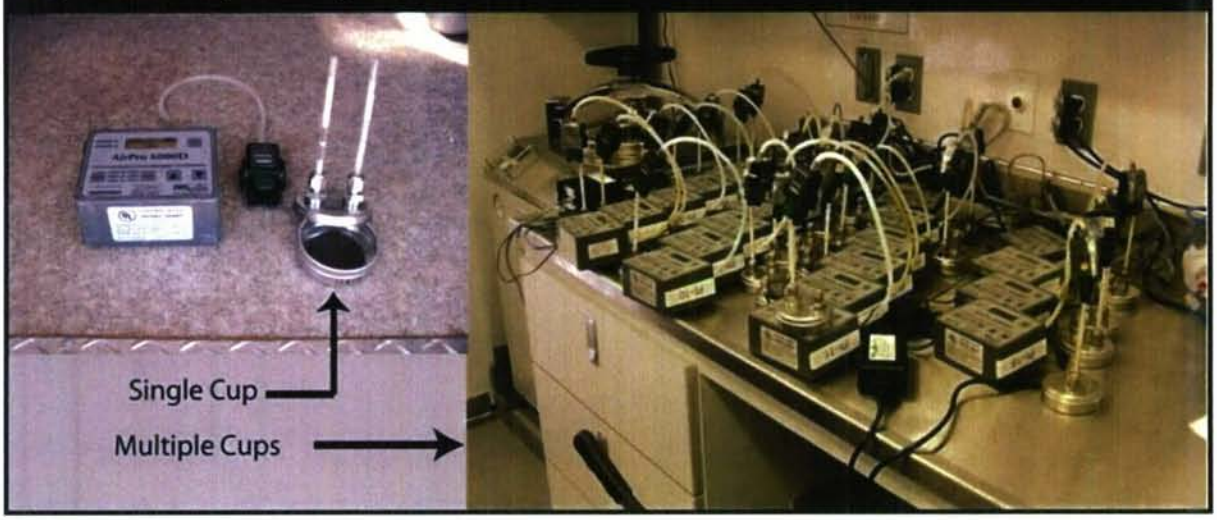
The coupons were removed from the aircraft following the indicated decontamination period and immediately placed in the vapor cups for analysis. Vacuum lines were immediately connected to the exit ports and the timed cup evacuation was started. Ambient air, conditioned through a charcoal (BPL 30 to 40 mesh) trap, was forced into the cups and made to flow at a pre-set rate of 400 or 200 mL/min. The February 28 set had a measured flow of

conditioned air through the vapor cup of 400 mL/min, and was decreased to 200 mL/min during subsequent runs. The air stream leaving the cup exited through a DAAMS tube to absorb any CEPS that off-gassed (volatilized) from the test coupon. Each sample period lasted 60 min to yield a total volume of air of 0.0120 m^3. The DAAMS tubes were then removed and stored in capped glass containers until analyzed. Figure 2.14 shows the vapor cup with DAAMS tube and corresponding pump.

The concentration of CEPS remaining was reported as milligrams (mg) per cubic meter (m^3). This concentration was determined from the mass of CEPS detected by the GC, reported in nanograms and the total volume of conditioned air passed over the coupon while sealed in the vapor cup. The following expression was used to calculate this concentration:

[CEPS] mg/m^3 = (Mass of CEPS (ng)) (1 x 10^{-6} mg/ng)/(flow rate (cm^3/min) (60-min)(1 x 10^{-6} m^3/cm^3))

Figure 2.14: Vapor Sampling



The concentration of CEPS vapor was determined by a gas chromatograph (GC) separation and detection using a flame photometric detector (FPD) in the sulfur mode. Each DAAMS tube was inserted into Dynatherm, which was designed to thermally desorb the analyte from the DAAMS Tenax solid sorbent and transfer the vapor into the coupled Agilent 6852 GC inlet. The column was a 0.25 mm x 15 m DB-210 with N_2 carrier at 10 psi. The initial column temperature of 60 °C was held for 1 min and then ramped to 200 °C at 45 °C/min. The injector and detector temperatures were 250 °C and 300 °C, respectively.

2.15 Analytical Procedures.

A quality control process was employed throughout the analysis of the test samples. Quality Process and Quality Lab samples were taken IAW the US Army Technical Escort Unit's Quality Assurance Plan (US Army TEU Aberdeen Proving Ground, January 2004). Prior to the sample analysis a 6-point external calibration standard curve was created each day

samples were to be analyzed. The calibration samples were followed by initial calibration verification (ICV) and subsequent periodic continuation calibration verification (CCV) samples. The ICV and CCV compared the found mass to the expected mass of the analyte (CEPS). If the result deviated more than 5% the instrument was re-calibrated.

2.16 Weather Conditions.

On each day of testing, various weather conditions were recorded; and a summary is provided in Table 2.16.

Table 2.16: Weather Conditions

Date of Test	2/27/2006	2/28/2006	3/1/2006	3/2/2006	3/7/2006	3/8/2006
Temperature °F						
Maximum	81	81	68	79	73	61
Time Achieved	16:10	14:45	12:47	16:38	16:54	16:30
Minimum	44	54	52	44	57	44
Time Achieved	5:59	5:08	23:56	7:03	7:41	23:59
Daily Average	63	68	60	62	65	53
Relative Humidity, %						
Maximum	18	31	67	76	40	48
Minimum	5	11	31	6	12	23
Daily Average	12	21	49	41	26	36
Daily Average Wind Speed, MPH	5.8	8	4.5	5.5	6.7	9.1

3. TEST RESULTS AND DISCUSSION

3.1 Test Summary.

Six efficacy tests were completed during this demonstration. Biological indicators were used during each test. Chemical coupons were tested on days when mVHP was used (Table 3.1). The 8 March 2006 test incorporated a special scenario of having a 30-min power outage during the decontamination phase. The purpose was to show that if there was an outage during the decontamination cycle, the decontamination time would stop and only resume once the target concentration was again reached. The length of time at the target decontamination concentration was 4 hr.

Table 3.1: Test Details						
Date of Test	Fumigant	Cycle Length (hrs)	Target Concentration (ppm H2O2 / ppm NH3)	Chemical Coupons	Bio. Coupons	BIs
2/27/2006	VHP	2	500 / 0		✓	✓
2/28/2006	mVHP	3	500 / 30	✓		✓
3/2/2006	VHP	4	500 / 0		✓	✓
3/3/2006	mVHP	5	500 / 30	✓		✓
3/7/2006	mVHP	4	500 / 30	✓	✓	✓
3/8/2006	VHP	4	500 / 0		✓	✓

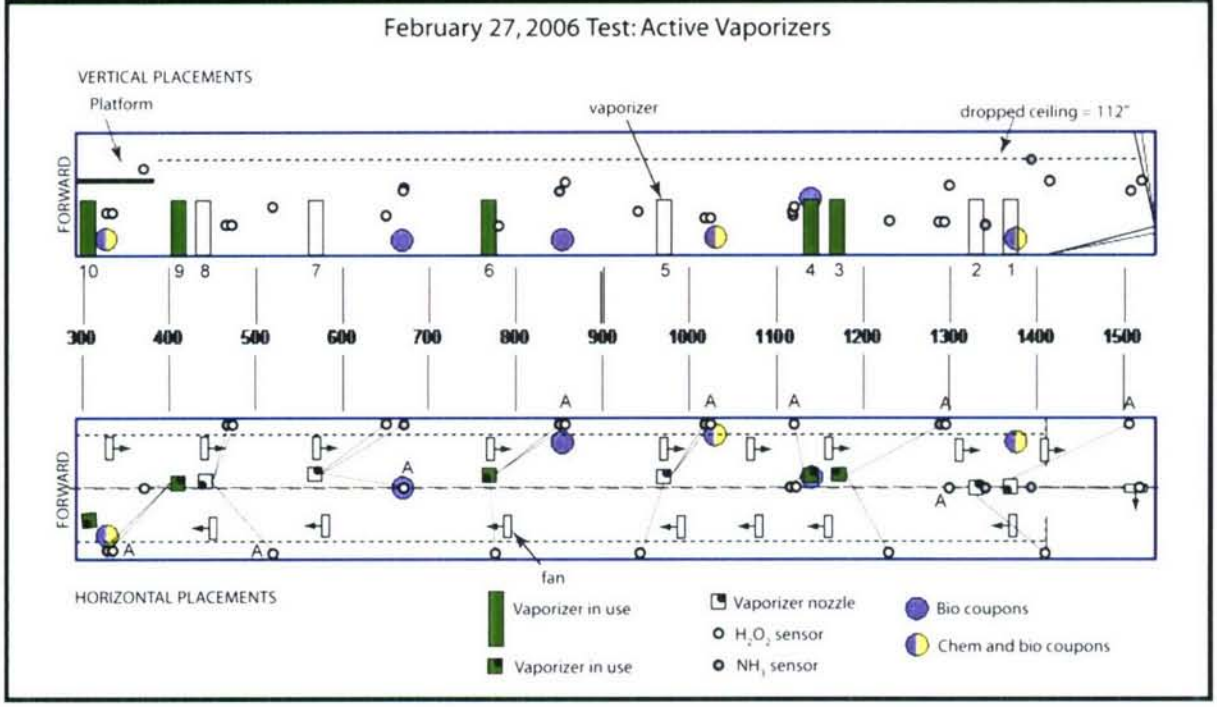
3.2 Test 1: 27 February 2006.

The 27 February, 2006 test was an efficacy test employing VHP. Biological coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.2.1 Operational Results.

The 27 February 2006 test was a 2-hr decontamination test using 500-ppm hydrogen peroxide only (VHP). The test utilized vaporizers 3, 4, 6, 9, & 10. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Figure 3.2.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 41.39 °C ± 0.31 and 6.29% ± 0.38, respectively.

Figure 3.2.1: Active Vaporizers - Feb. 27th



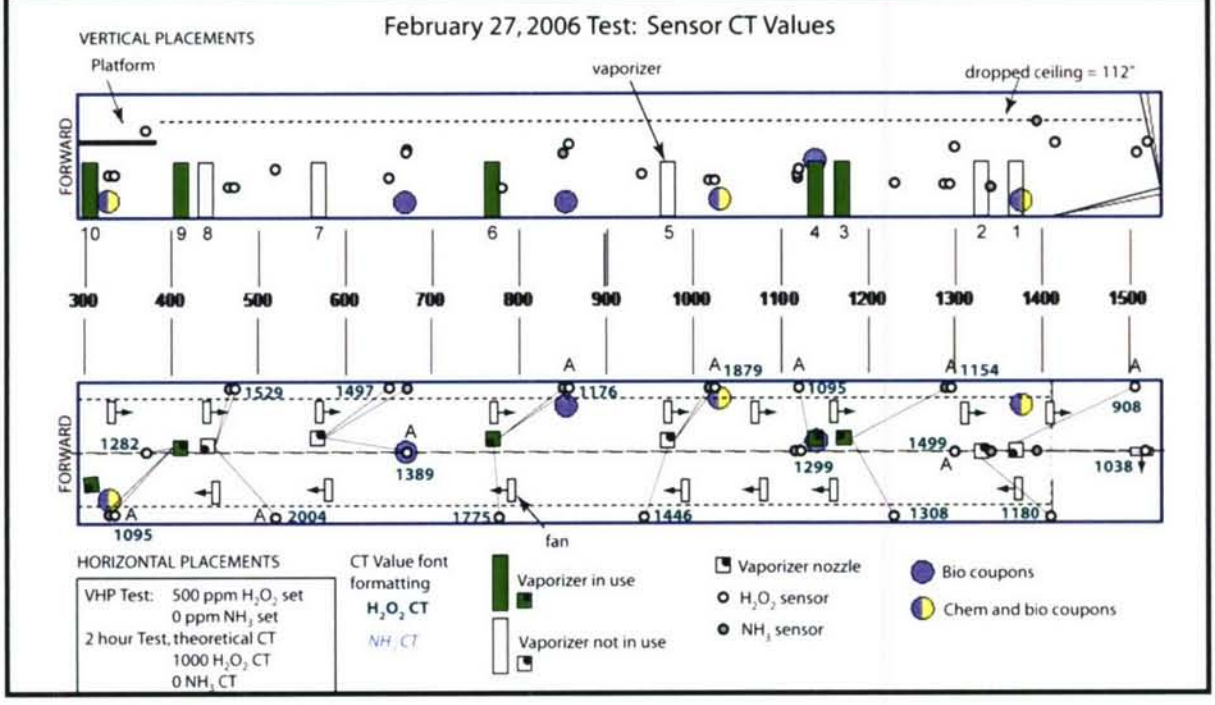
3.2.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) are provided in Table 3.2.2.1. The decontamination time for this test was 2 hr. The entire cycle time of this test was 4 hr. The average CT for all 18 hydrogen peroxide sensors was 1364 ppm-hr. Although no ammonia was introduced in this test, the ammonia sensors sometimes show a small reading in the presence of hydrogen peroxide resulting in the average CT of 3.3 ppm-hr for the 9 sensors. The target CT for hydrogen peroxide was 1000 ppm-hr. The values recorded in Table 3.2.2.1 are also shown in Figure 3.2.2.

Table 3.2.2.1: 2/27/06 CT readings for each Vaporizer (ppm-hr)

Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	907.46	1038.12	3.42
2	1499.35	1179.70	1.12
3	1153.68	1307.84	5.41
4	1095.34	1299.38	1.47
5	1878.88	1446.36	4.11
6	1175.84	1775.02	7.13
7	1388.84	1496.63	2.64
8	2003.84	1528.88	0.97
9	1094.57	1281.79	3.50

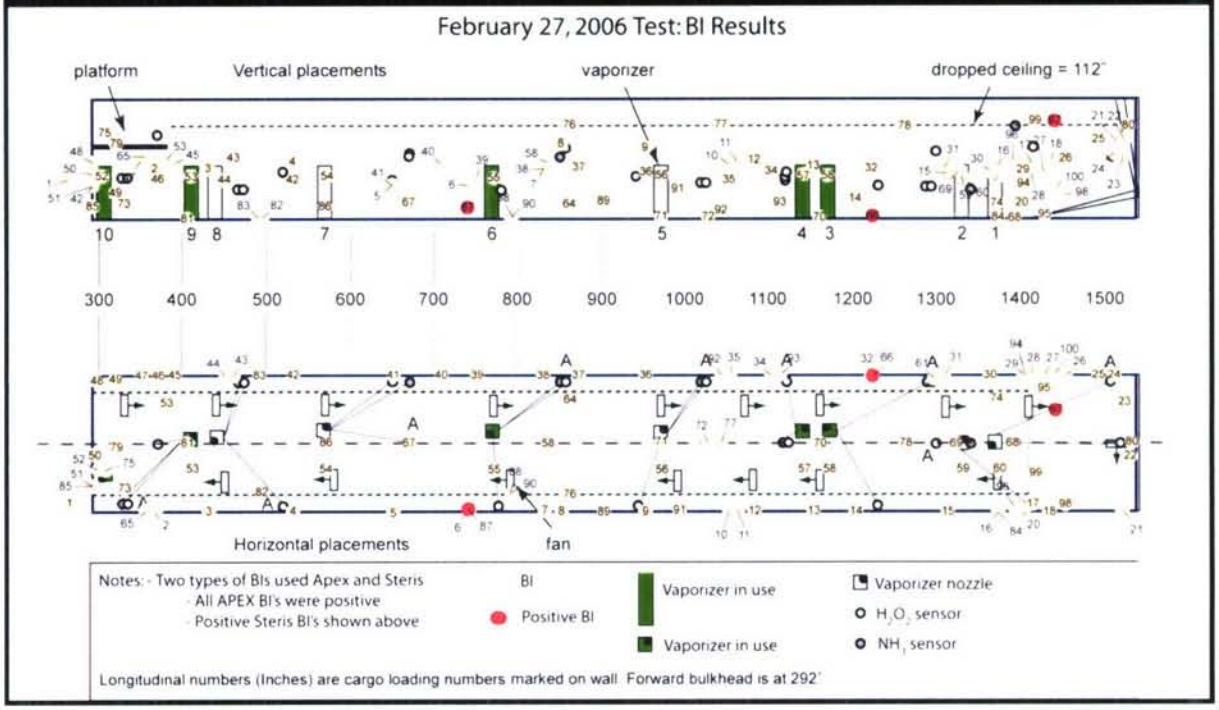
Figure 3.2.2: Sensor CT Values - Feb. 27th



3.2.3 BI Results.

One hundred Apex (ATCC 12980, Lot H3355 Exp. 31 Jul 06) and 100 Steris (ATCC 7953, Lot 0306 Exp. 30 Oct 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to seven days. All Apex BIs except in locations 31, 37, 38, 43, 44, and 49 were positive for growth. Those mentioned were negative after 1 day, but positive thereafter. All Steris BIs with the exceptions of 61, 66, and 97 were negative for growth. The Steris BIs in the afore-mentioned locations were positive for growth after each day following testing. Figure 3.2.3 diagrams locations of all BIs used during the February 27 test. Positive BIs were indicated by a red dot, whereas negative BIs were indicated with a tan dot.

Figure 3.2.3: BI Results - Feb. 27th



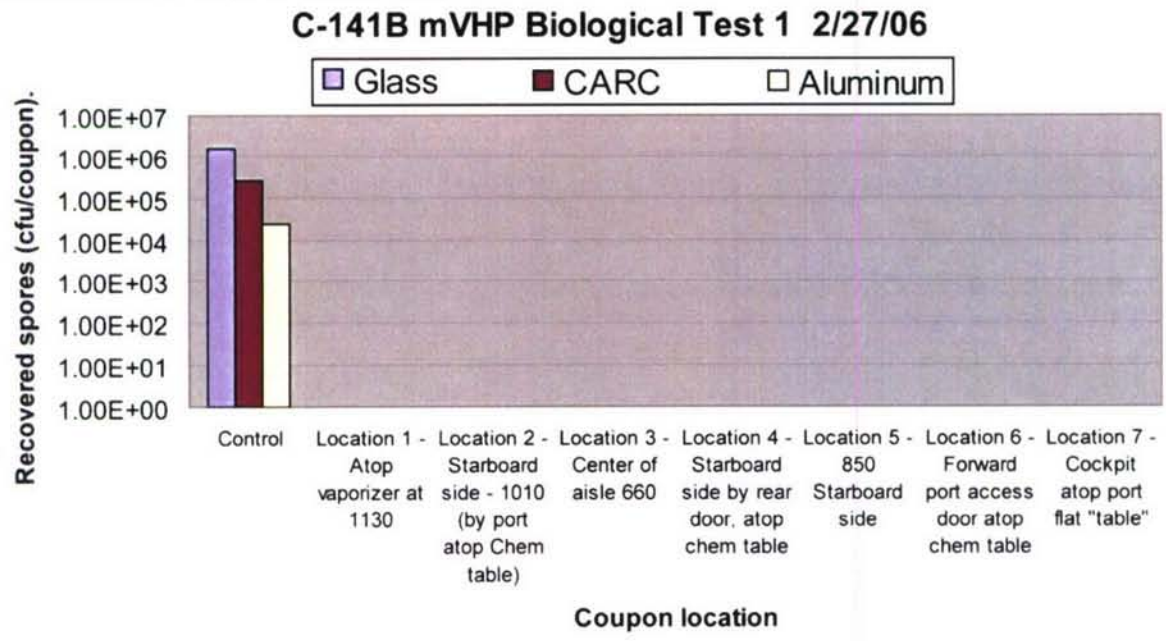
3.2.4 Biological Coupon Results.

As mentioned in Section 2.9, four biological coupons of each of the three functional materials (glass, aluminum, CARC) were prepared and deposited into the aircraft for the test. Coupon locations were shown in Table 2.9.1.

Coupons were placed in each of the seven locations for a total of 84 coupons. A coupon from each location for each material was placed in broth and monitored for growth. All coupons showed no growth with the exception of CARC at location 1. After plating the three replicate CARC coupons at location 1, they were enumerated. No CFU were found on any of the enumerated replicates.

Figure 3.2.4 shows no growth was observed for any location or functional material. The control samples were prepared and enumerated. The glass control sample showed 1.52E6 CFU/coupon, which was expected. The CARC control sample recoveries were lower than seen in other studies at 2.64E5 CFU/coupon. The aluminum control samples showed the lowest recovery at 2.27E4 CFU/coupon.

Figure 3.2.4: Biological Coupon Results - Feb. 27th



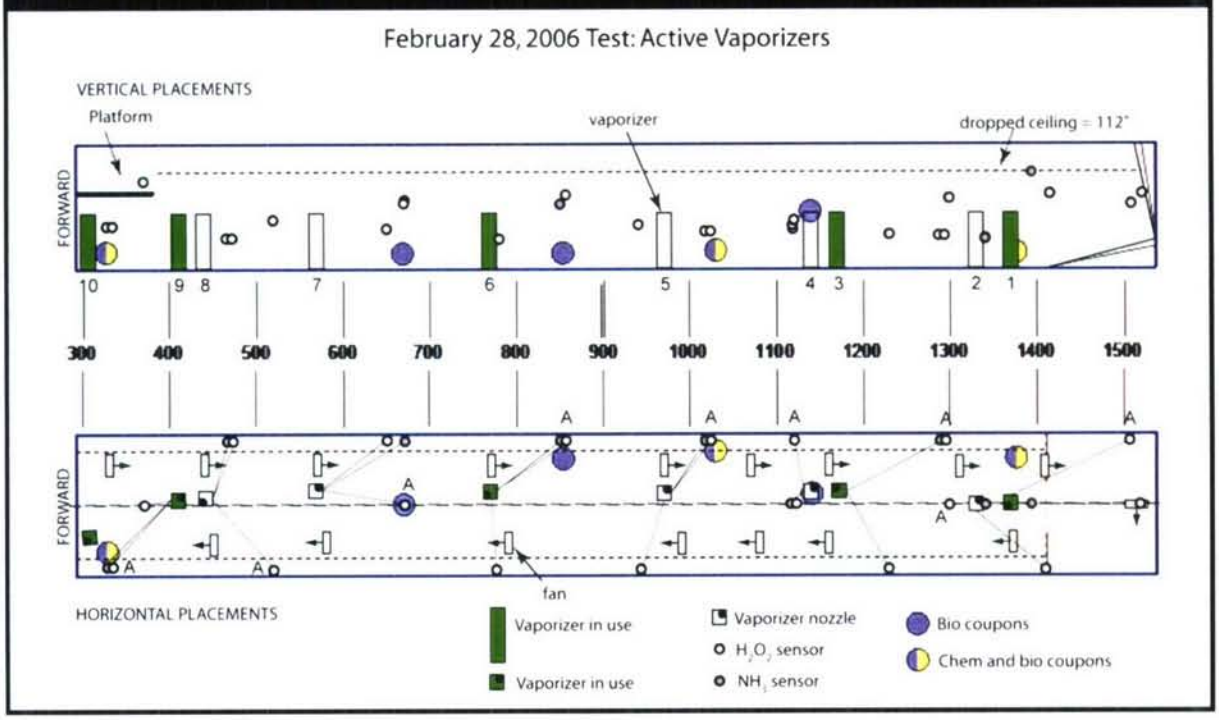
3.3 Test 2: 28 February 2006.

The 28 February, 2006 test was an efficacy test employing mVHP. Chemical coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.3.1 Operational Results.

The 28 February 2006 test was a 2-hr decontamination phase treatment using 500-ppm hydrogen peroxide and 30-ppm ammonia (mVHP). The test utilized vaporizers 1, 3, 6, 9, and 10. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Vaporizer 3 was only on for the first 15 min, and off afterwards. Figure 3.3.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 38.72 °C ± 0.85 and 9.37% ± 0.47, respectively.

Figure 3.3.1: Active Vaporizers - Feb. 28th



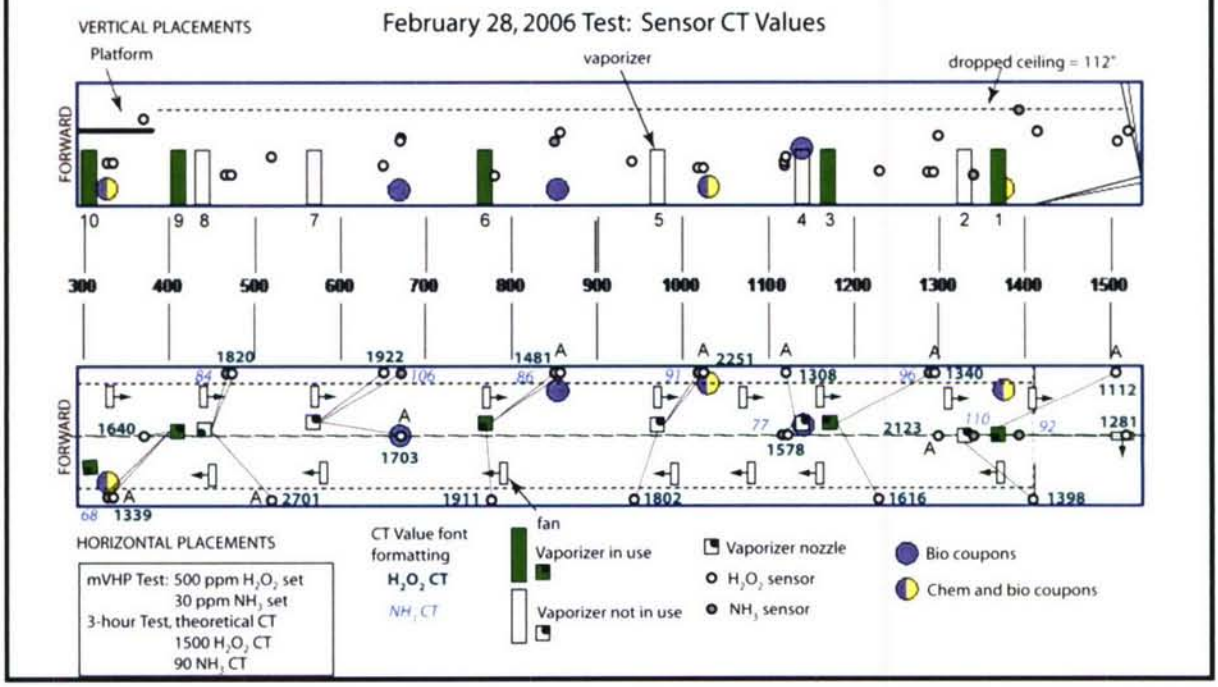
3.3.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) were provided in Table 3.3.2.1. The decontamination time for this test was 3 hr. The entire cycle time of this test was 5 hr and 47 min. The average CT for all 18 hydrogen peroxide sensors was 1364 ppm-hr. The average CT for ammonia for all 9 sensors was 87 ppm-hr. The target CTs for hydrogen peroxide and ammonia were 1500 and 90 ppm-hr, respectively. The values recorded in Table 3.3.2.1 are also shown in Figure 3.3.2.

Table 3.3.2.1: 2/28/06 CT readings for each Vaporizer (ppm-hr)

Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	1111.78	1280.80	91.82
2	2122.66	1398.36	109.87
3	1340.44	1616.27	96.21
4	1308.28	1577.71	76.79
5	2250.55	1801.53	90.70
6	1480.88	1910.81	86.20
7	1702.90	1921.49	105.76
8	2701.26	1819.53	83.57
9	1338.46	1639.68	67.83

Figure 3.3.2: Sensor CT Values - Feb. 28th



3.3.3 BI Results.

One hundred Apex (ATCC 12980, Lot H3355 Exp. 31 Jul 06) and 100 Steris (ATCC 7953, Lot 0306 Exp. 30 Oct 06, 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to 7 days. All Apex BIs except in locations 33, 36, 44, 47, and 50 were positive for growth. Those mentioned were negative after 1 day, but positive thereafter. All Steris BIs with the exceptions of 16, 26, and 80 were negative for growth. The Steris BIs in the aforementioned locations were positive for growth after each day following testing. Figure 3.3.3 diagrams locations of all BIs used during the February 28 test.

3.3.4 Chemical Coupon Results.

3.3.4.1 Vapor Analysis of Headspace.

During the first chemical agent surrogate test a limited number of coupons were inserted into the aircraft. Only two replicates for each surface at each location were included. The limited number of samples was due to required adjustments with sampling pumps, which was resolved prior to the next test.

The results of the CEPS vapor analysis from the February 28 test were included in Table 3.3.4.1. The aircraft (A/C) locations correspond to the descriptions from Section 2.12. The mass of the CEPS measured by the GC and the mass/volume concen-tration, calculated from the measured total volume of air flow over the sample, were included in the final two columns. The

JPID threshold and objective values were 0.0058 mg/m^3 and 0.003 mg/m^3, respectively. Comparing the mass/volume concentration of CEPS, the remaining vapor levels were below both the JPID threshold and objective limit.

Figure 3.3.3: BI Results - Feb. 28th

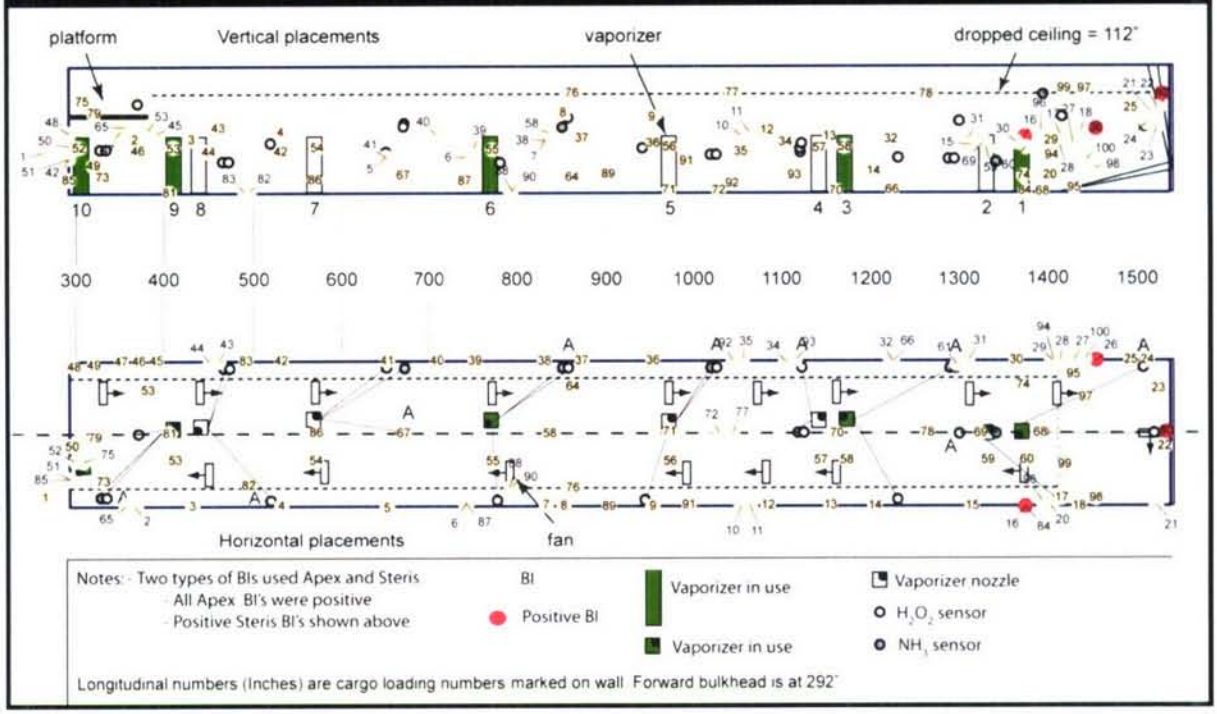


Table 3.3.4.1: February 28 Vapor Analysis Results

Surface	A/C Location	CEPS, ng	CEPS, mg/m3
Aluminum	Forward	1.7	0.0001
Aluminum	Forward	1.4	0.0001
CARC	Forward	39.0	0.0016
CARC	Forward	3.2	0.0018
Aluminum	Amidships	3.2	0.0001
Aluminum	Amidships	2.8	0.0001
CARC	Amidships	48.0	0.0020
CARC	Amidships	49.9	0.0021
Aluminum	Rear	1.2	0.0000
Aluminum	Rear	3.2	0.0001
CARC	Rear	48.0	0.0020
CARC	Rear	Sample Lost	----

3.3.4.2 Contact Exposure Analysis.

The contact exposure results from the February 28 test were listed in Table 3.3.4.2. The 15-min contact time represents the amount of time the latex was in contact with the contaminated side of the test coupon. Similarly, the 45-min contact time represents a second piece of latex inserted following the 15-min contact period, which permitted a total contact time of 60 min. The results indicate that CEPS was not detected (ND) on most of the sample coupons. In samples where CEPS was detected, the concentration was above JPID ORD threshold contact exposure level for blister-H (<3.0 mg/m^2).

Table 3.3.4.2: February 28 Contact Analysis Results

Surface	Contact Time, min	A/C Location	CEPS, ng/uL	CEPS, ng/coupon	CEPS, mg/m2	Surface	Contact Time, min	A/C Location	CEPS, ng/uL	CEPS, ng/coupon	CEPS, mg/m2
CARC	15	1	ND	0	0.00	CARC	45	1	1.2593	12593	6.20
CARC	15	1	ND	0	0.00	CARC	45	1	1.2992	12992	6.40
CARC	15	2	ND	0	0.00	CARC	45	2	ND	0	0.00
CARC	15	2	1.4418	14418	7.10	CARC	45	2	1.4130	14130	6.96
CARC	15	3	ND	0	0.00	CARC	45	3	ND	0	0.00
CARC	15	3	ND	0	0.00	CARC	45	3	1.4739	14739	7.26
Aluminum	15	1	ND	0	0.00	Aluminum	45	1	1.2916	12916	6.36
Aluminum	15	1	ND	0	0.00	Aluminum	45	1	1.2611	12611	6.21
Aluminum	15	2	ND	0	0.00	Aluminum	45	2	ND	0	0.00
Aluminum	15	2	ND	0	0.00	Aluminum	45	2	ND	0	0.00
Aluminum	15	3	1.3100	13100	6.45	Aluminum	45	3	1.3669	13669	6.73
Aluminum	15	3	ND	0	0.00	Aluminum	45	3	ND	0	0.00

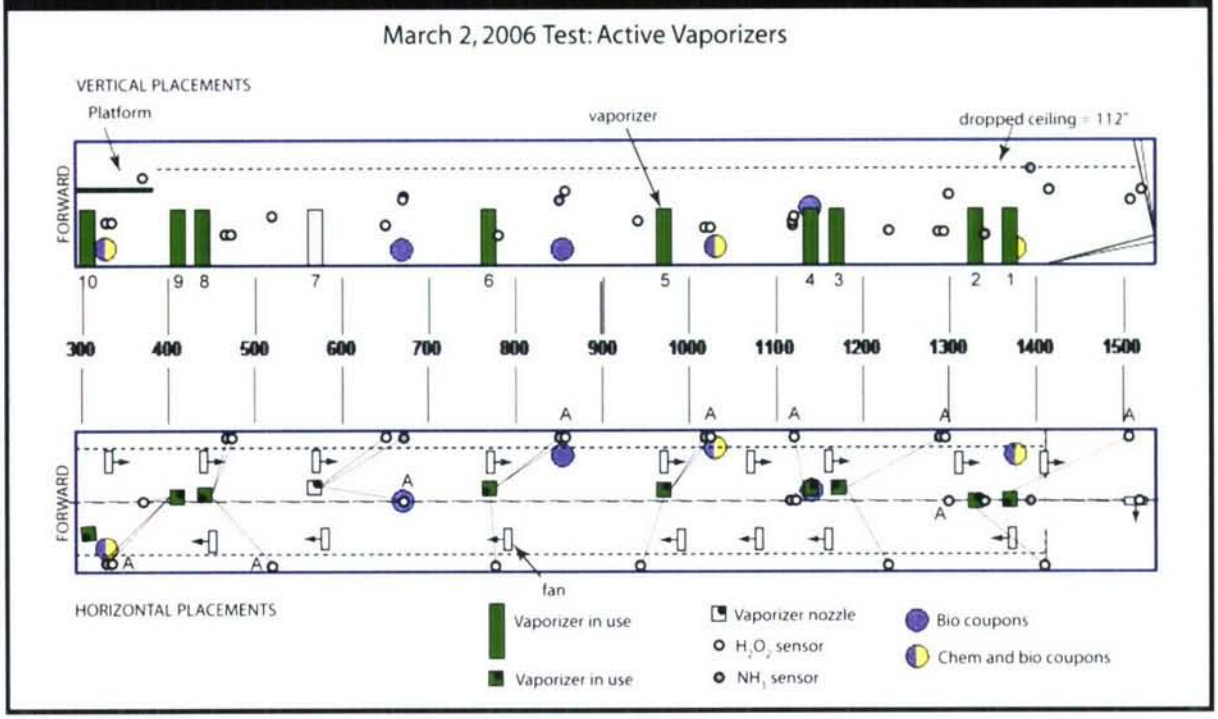
3.4 Test 3: 2 March 2006.

The 2 March 2006 test was an efficacy test employing VHP. Biological coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.4.1 Operational Results.

The 2 March 2006 test was a 4-hr decontamination using 500-ppm hydrogen peroxide (VHP). The test utilized every vaporizer, with the exception of vaporizer 7. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Figure 3.4.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 35.45 °C ± 1.82 and 17.83% ± 2.29, respectively.

Figure 3.4.1: Active Vaporizers - Mar. 2nd



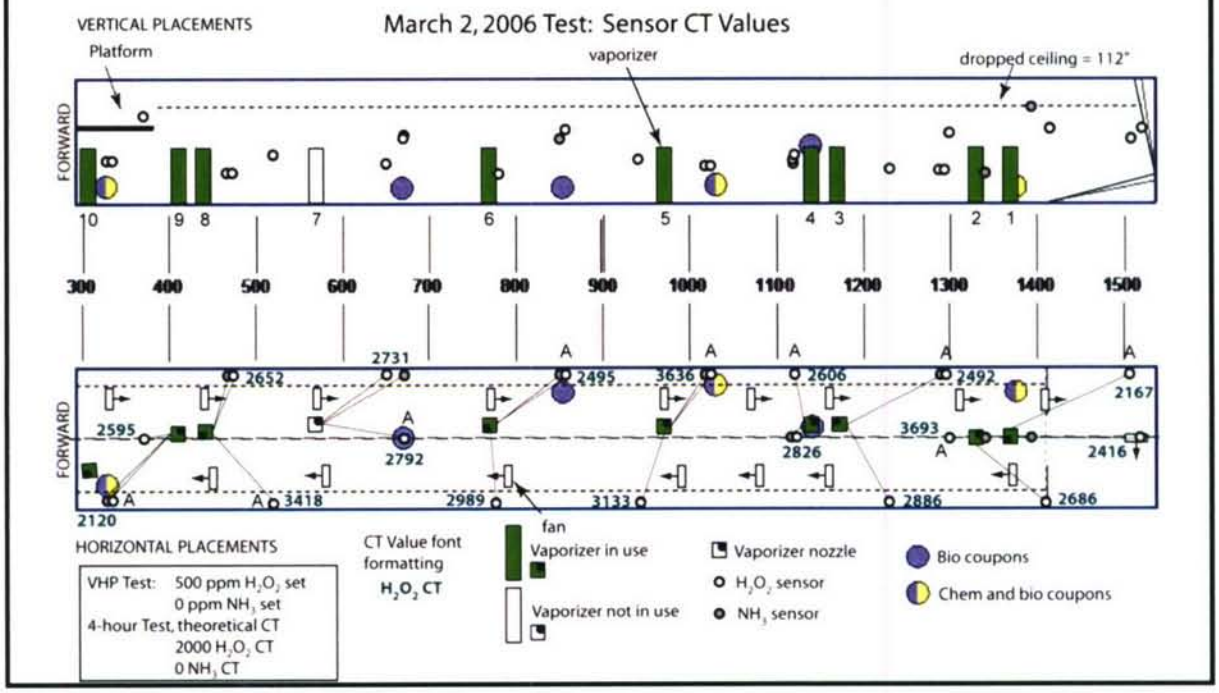
3.4.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) were provided in Table 3.4.2.1. The decontamination time for this test was 4 hr. The entire cycle time of this test was 6 hr and 2 min. The average CT for all 18 hydrogen peroxide sensors was 2796 ppm-hr. Although no ammonia was introduced in this test, the ammonia sensors sometimes show a small reading in the presence of hydrogen peroxide resulting in the average CT of 9.4 ppm-hr for the 9 sensors. The target CT for hydrogen peroxide was 2000 ppm-hr. The values recorded in Table 3.4.2.1 are also shown in Figure 3.4.2.

Table 3.4.2.1: 3/2/06 CT readings for each Vaporizer (ppm-hr)

Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	2167.38	2415.90	11.43
2	3692.58	2685.68	12.88
3	2491.88	2885.65	15.17
4	2605.80	2826.10	2.93
5	3635.74	3133.44	6.14
6	2494.85	2989.40	8.74
7	2791.83	2730.50	10.58
8	3417.58	2651.62	10.00
9	2120.27	2594.49	7.30

Figure 3.4.2: Sensor CT Values - Mar. 2nd



3.4.3 BI Results

One hundred Apex (ATCC 12980, Lot H3355 Exp. 31 Jul 06) and 100 Steris (ATCC 7953, Lot 0306 Exp. 30 Oct 06, 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to seven days. All Apex BIs except in locations 31, 63, 84, and 97 were negative for growth. Those mentioned were positive after each day following testing. All Steris were negative for growth after each day following testing. Figure 3.4.3 diagrams locations of all BIs used during the March 2 test.

3.4.4 Biological Coupon Results.

As mentioned in Section 2.9, four biological coupons of each of the three functional materials (glass, aluminum, CARC) was prepared and deposited into the aircraft for the test. Coupon locations were outlined in Table 2.9.1.

Coupons were placed in each of the seven locations for a total of 84 coupons. A coupon of each material type and from each location was placed in broth. Only samples showing growth in the broth treatment were plated. All coupons showed no growth in the broth.

Figure 3.4.4 indicates that no growth was observed for any location or functional material. The three control samples prepared on February 27th showed average growth for 1.52E6 on glass, 2.64E5 on CARC and 2.27E4 on aluminum.

Figure 3.4.3: BI Results - Mar. 2nd

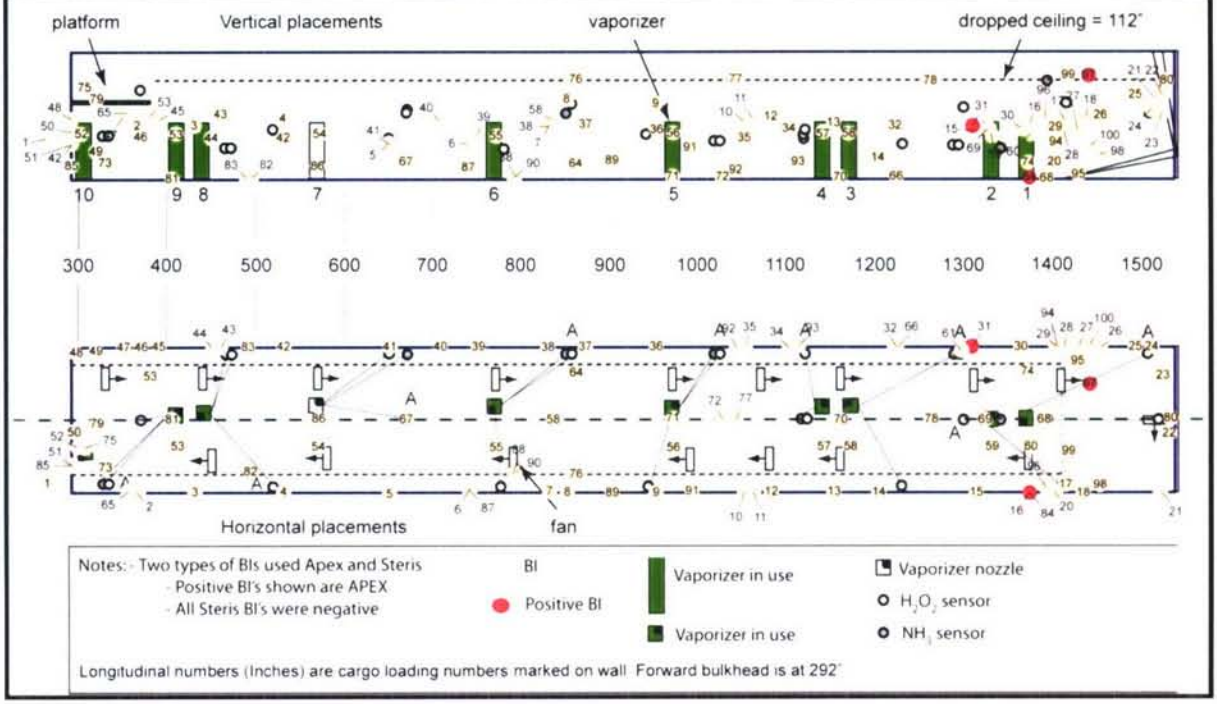
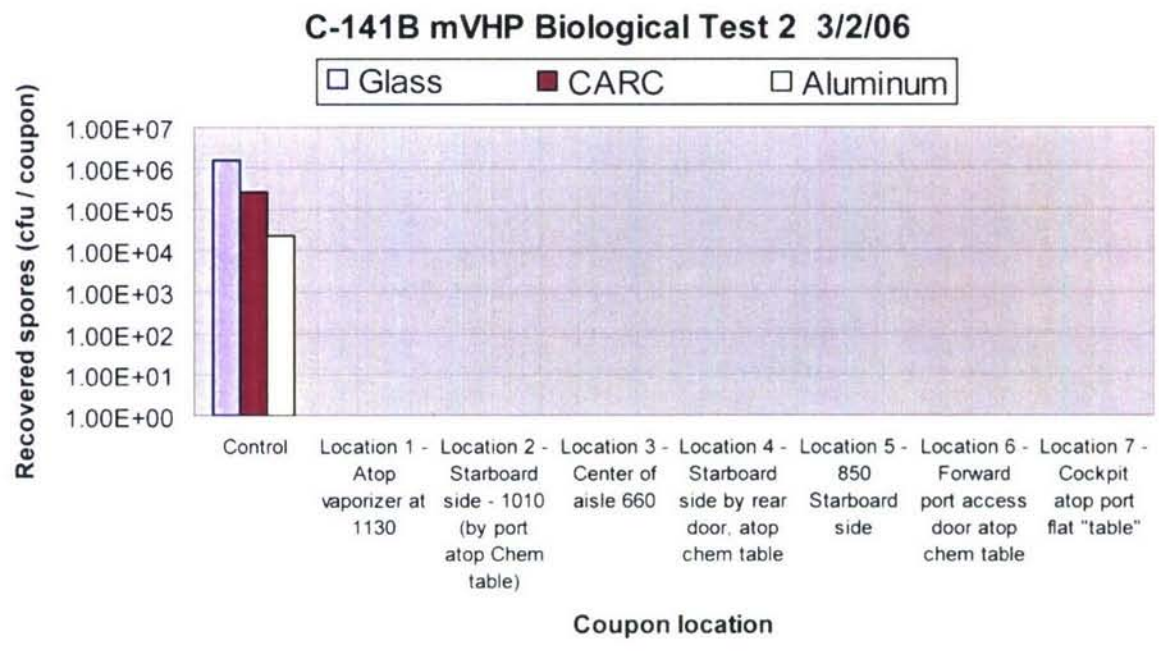


Figure 3.4.4: Biological Coupon Results - Mar. 2nd



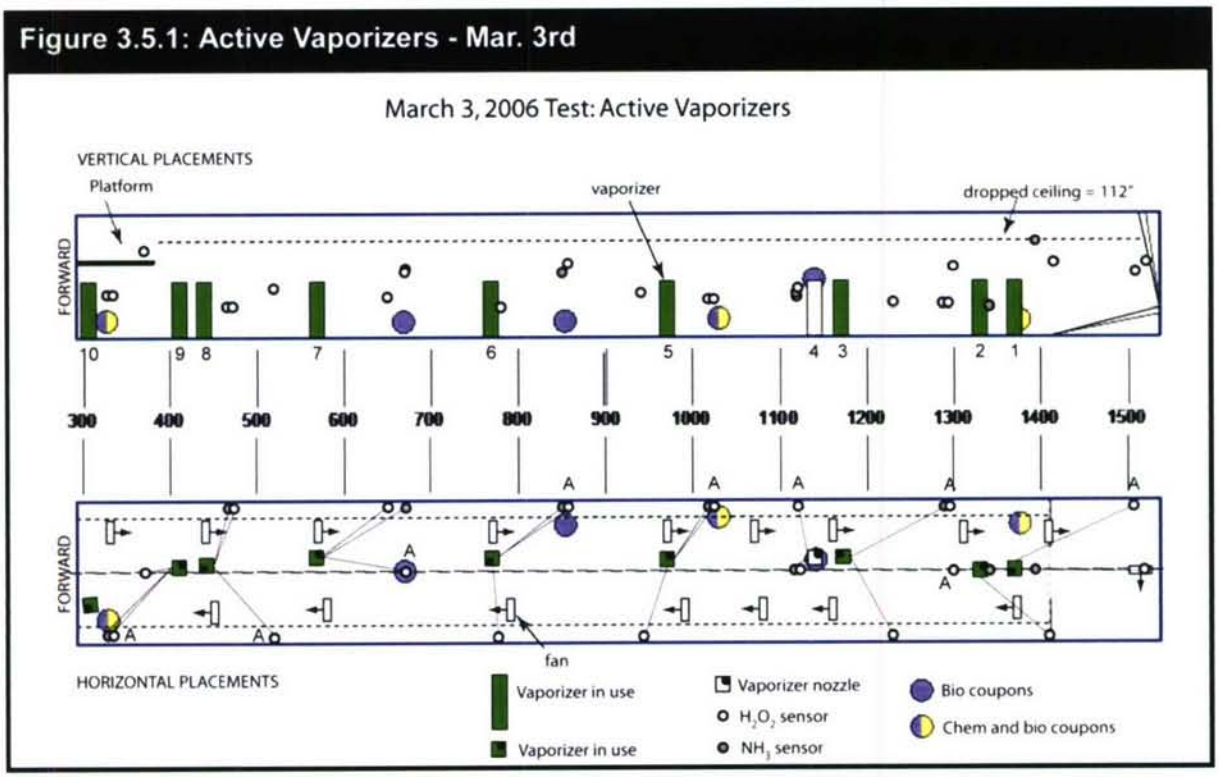
3.5 Test 4: 3 March 2006.

The 3 March 2006 test was an efficacy test employing mVHP. Chemical coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.5.1 Operational Results.

The 3 March 2006 test was a 5-hr decontamination using 500-ppm hydrogen peroxide and 30-ppm ammonia (mVHP). The test utilized every vaporizer, with the exception of vaporizer 4. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Figure 3.5.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 32.91 °C ± 1.06 and 19.52% ± 0.58, respectively.

Figure 3.5.1: Active Vaporizers - Mar. 3rd



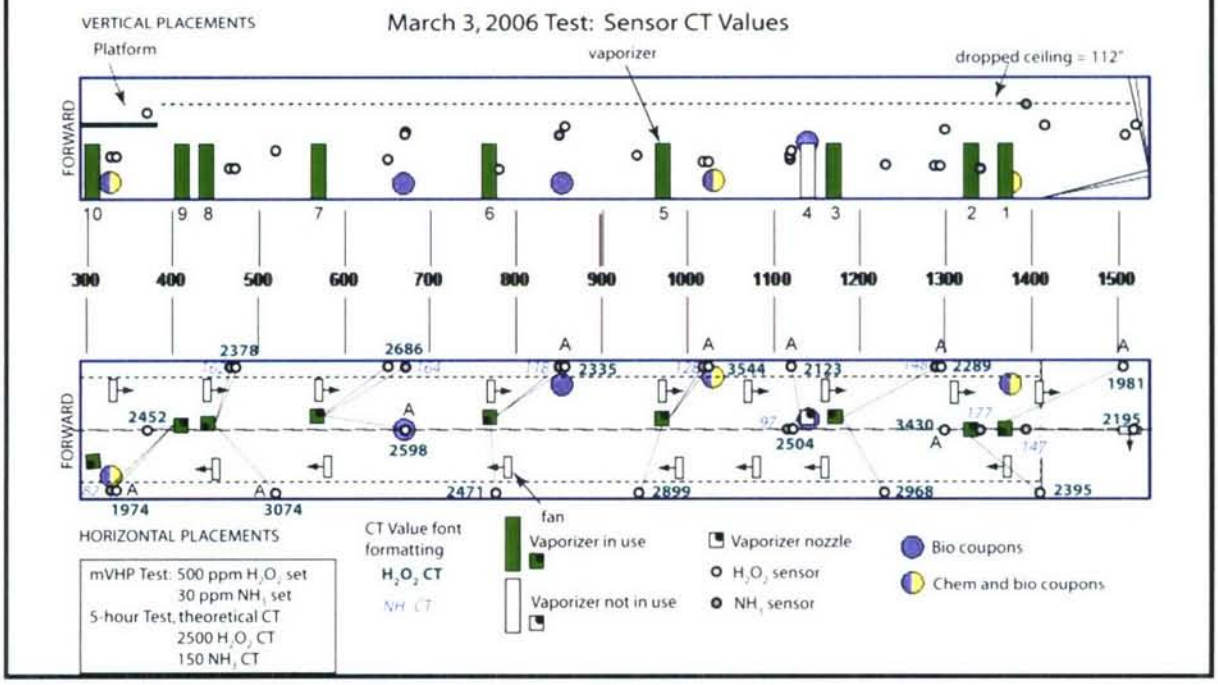
3.5.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) were provided in Table 3.5.2.1. The decontamination time for this test was 5 hr. The entire cycle time of this test was 7 hr and 36 min. The average CT for all 18 hydrogen peroxide sensors was 2572 ppm-hr. The average CT for ammonia for all 9 sensors was 136 ppm-hr. The target CTs for hydrogen peroxide and ammonia was 2500 and 150 ppm-hr, respectively. The values recorded in Table 3.5.2.1 are also shown in Figure 3.5.2.

Table 3.5.2.1: 3/3/06 CT readings for each Vaporizer (ppm-hr)

Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	1980.69	2195.01	146.73
2	3429.70	2394.80	177.05
3	2288.68	2967.94	148.43
4	2123.08	2504.33	96.68
5	3544.42	2899.13	128.29
6	2334.54	2470.72	117.56
7	2598.38	2686.39	163.68
8	3073.85	2378.33	161.49
9	1973.46	2452.41	81.99

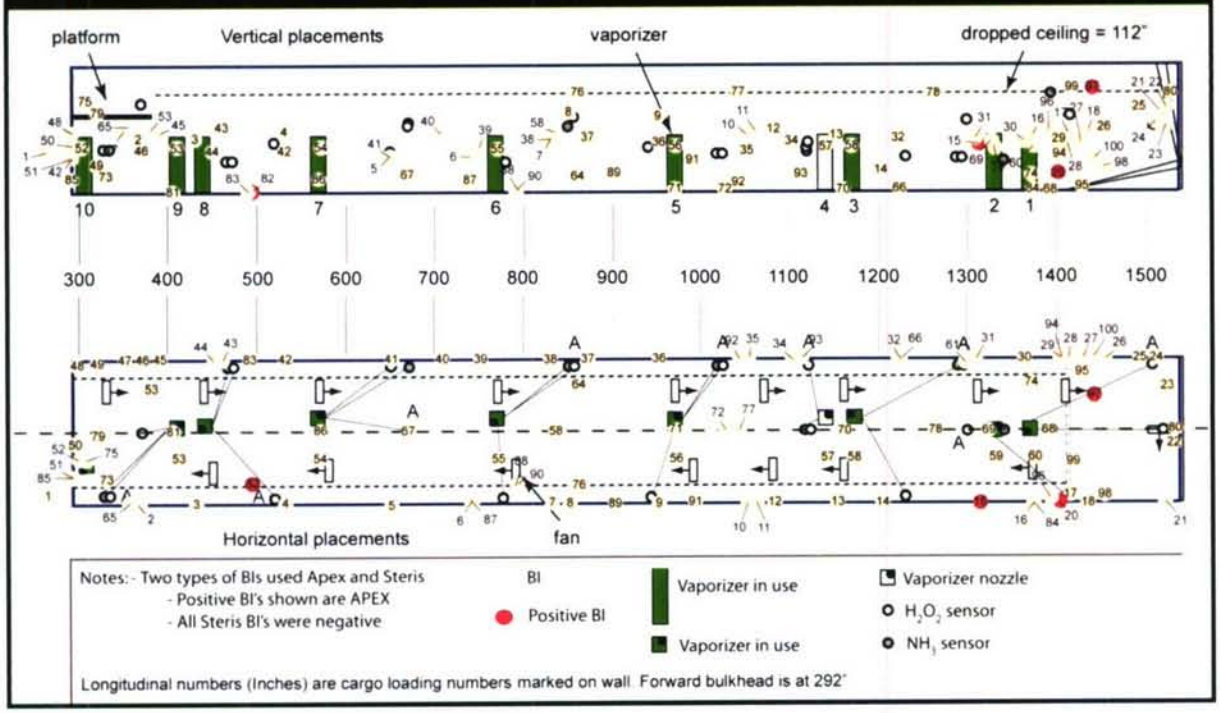
Figure 3.5.2: Sensor CT Values - Mar. 3rd



3.5.3 BI Results.

One hundred Apex (ATCC 12980, Lot H3355 Exp. 31 Jul 06) and 100 Steris (ATCC 7953, Lot 0306 Exp. 30 Oct 06, 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to seven days. All Apex BIs except in locations 15, 82, and 97 were negative for growth. Those mentioned were positive after each day following testing. All Steris BIs were negative for growth after each day following testing. Figure 3.5.3 shows locations of all BIs used during the March 3 test.

Figure 3.5.3: BI Results - Mar. 3rd



3.5.4 Chemical Coupon Results.

3.5.4.1 Vapor Analysis of Headspace.

The results of the CEPS vapor analysis from the March 3rd test were included in Table 3.5.4.1. The aircraft (A/C) locations correspond to the descriptions from Section 2.12. The mass of the CEPS measured by the GC and the mass/volume concentration, calculated from the measured total volume of air flow over the sample, were included in the final two columns. The JPID threshold and objective values were 0.0058 mg/m^{3}and 0.003 mg/m^3, respectively. Comparing the mass/volume concentration of CEPS, the remaining CEPS levels were below the JPID threshold and objective values.

Table 3.5.4.1: March 3 Vapor Analysis Results			
Surface	**A/C Location**	**CEPS, ng**	**CEPS, mg/m3**
Aluminum	Forward	1.0000	0.0008
Aluminum	Forward	1.0000	0.0008
Aluminum	Forward	1.0000	0.0008
Aluminum	Forward	1.0000	0.0008
CARC	Forward	11.8840	0.0010
CARC	Forward	9.9360	0.0008
CARC	Forward	15.1620	0.0013
CARC	Forward	14.4850	0.0012
Aluminum	Amidships	5.1460	0.0004
Aluminum	Amidships	1.0000	0.0008
Aluminum	Amidships	5.1410	0.0004
Aluminum	Amidships	1.0000	0.0008
CARC	Amidships	15.9960	0.0013
CARC	Amidships	27.0480	0.0023
CARC	Amidships	23.5030	0.0020
CARC	Amidships	25.1970	0.0021
Aluminum	Rear	1.0000	0.0008
Aluminum	Rear	1.0000	0.0008
Aluminum	Rear	1.0000	0.0008
Aluminum	Rear	1.0000	0.0008
CARC	Rear	16.3930	0.0014
CARC	Rear	22.2460	0.0019
CARC	Rear	16.7330	0.0014
CARC	Rear	27.2370	0.0023

3.5.4.2 Contact Exposure Analysis.

The contact exposure results from the March 3 test were listed in Table 3.5.4.2. The 15-min contact time represents the amount of time the latex was in contact with the contaminated side of the test coupon. Similarly, the 45-min contact time represents a second piece of latex inserted following the 15-min contact period, which permitted a total contact time

of 60 min. In samples where CEPS was detected, the concentration was above the JPID ORD threshold contact exposure level for blister-H (<3.0 mg/m^2).

Table 3.5.4.2: Mar 3 Contact Analysis Results

Surface	Contact Time, min	A/C Location	CEPS, ng/uL	CEPS, ng/coupon	CEPS, mg/m2	Surface	Contact Time, min	A/C Location	CEPS, ng/uL	CEPS, ng/coupon	CEPS, mg/m2
Aluminum	15	Forward	1.1750	11750	5.79	Aluminum	45	Forward	0.9620	9620	4.74
Aluminum	15	Forward	1.0280	10280	5.06	Aluminum	45	Forward	0.9140	9140	4.50
Aluminum	15	Forward	0.9600	9600	4.73	Aluminum	45	Forward	0.8920	8920	4.39
Aluminum	15	Forward	0.9840	9840	4.85	Aluminum	45	Forward	0.9540	9540	4.70
CARC	15	Forward	1.8680	18680	9.20	CARC	45	Forward	1.7700	17700	8.72
CARC	15	Forward	1.0230	10230	5.04	CARC	45	Forward	1.0180	10180	5.01
CARC	15	Forward	1.0320	10320	5.08	CARC	45	Forward	0.8960	8960	4.41
CARC	15	Forward	0.9950	9950	4.90	CARC	45	Forward	0.9110	9110	4.49
Aluminum	15	Amidships	0.9370	9370	4.62	Aluminum	45	Amidships	0.9080	9080	4.47
Aluminum	15	Amidships	1.0220	10220	5.03	Aluminum	45	Amidships	0.9870	9870	4.86
Aluminum	15	Amidships	0.9900	9900	4.88	Aluminum	45	Amidships	0.9540	9540	4.70
Aluminum	15	Amidships	1.0230	10230	5.04	Aluminum	45	Amidships	1.0030	10030	4.94
CARC	15	Amidships	0.9710	9710	4.78	CARC	45	Amidships	0.9560	9560	4.71
CARC	15	Amidships	1.0760	10760	5.30	CARC	45	Amidships	0.9130	9130	4.50
CARC	15	Amidships	0.9450	9450	4.66	CARC	45	Amidships	0.9110	9110	4.49
CARC	15	Amidships	0.9870	9870	4.86	CARC	45	Amidships	0.9450	9450	4.66
Aluminum	15	Rear	0.9880	9880	4.87	Aluminum	45	Rear	0.9920	9920	4.89
Aluminum	15	Rear	0.9860	9860	4.86	Aluminum	45	Rear	0.9020	9020	4.44
Aluminum	15	Rear	0.8920	8920	4.39	Aluminum	45	Rear	0.9120	9120	4.49
Aluminum	15	Rear	0.9550	9550	4.70	Aluminum	45	Rear	0.8780	8780	4.33
CARC	15	Rear	0.9460	9460	4.66	CARC	45	Rear	0.8810	8810	4.34
CARC	15	Rear	0.9490	9490	4.67	CARC	45	Rear	0.9080	9080	4.47
CARC	15	Rear	0.8530	8530	4.20	CARC	45	Rear	0.9160	9160	4.51
CARC	15	Rear	0.9260	9260	4.56	CARC	45	Rear	0.8870	8870	4.37

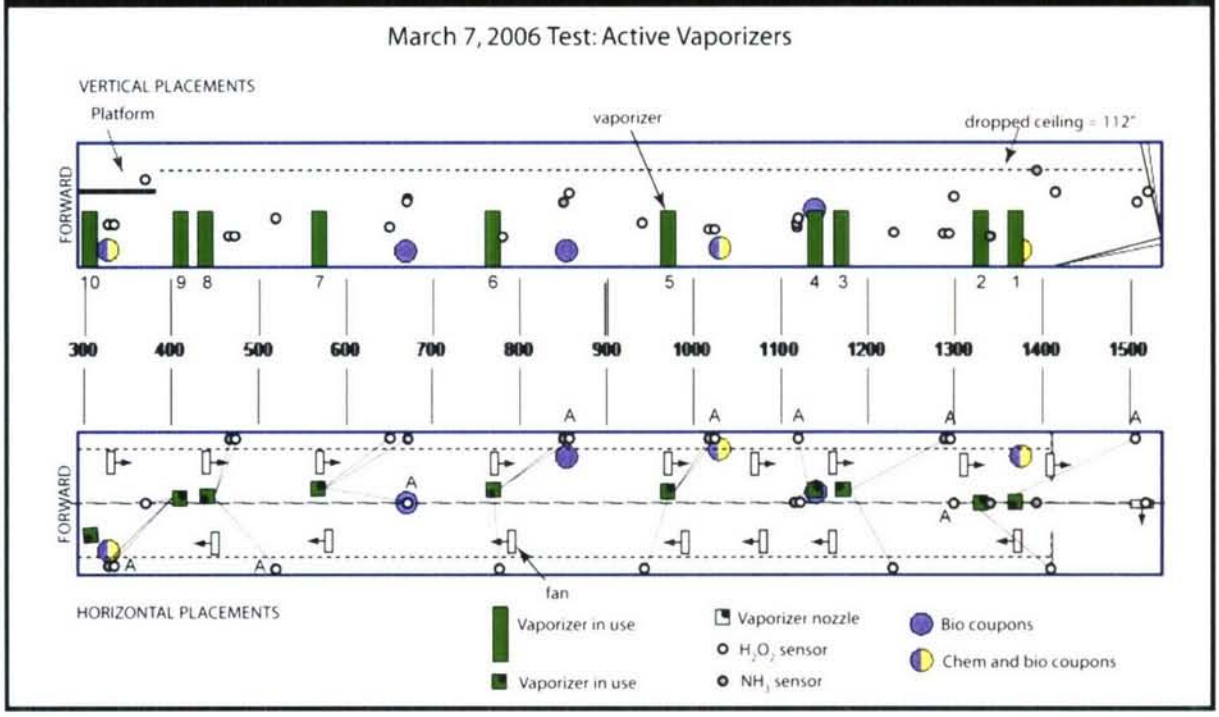
3.6 Test 5: 7 March 2006.

The 7 March 2006 test was an efficacy test employing mVHP. Biological coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.6.1 Operational Results.

The 7 March 2006 test was a 4-hr decontamination using 500-ppm hydrogen peroxide and 30-ppm ammonia (mVHP). The test utilized every vaporizer. Vaporizer 4 was turned to low air flow after 7 min. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Figure 3.6.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 33.81 °C ± 1.75 and 19.22% ± 1.21, respectively.

Figure 3.6.1: Active Vaporizers - Mar. 7th



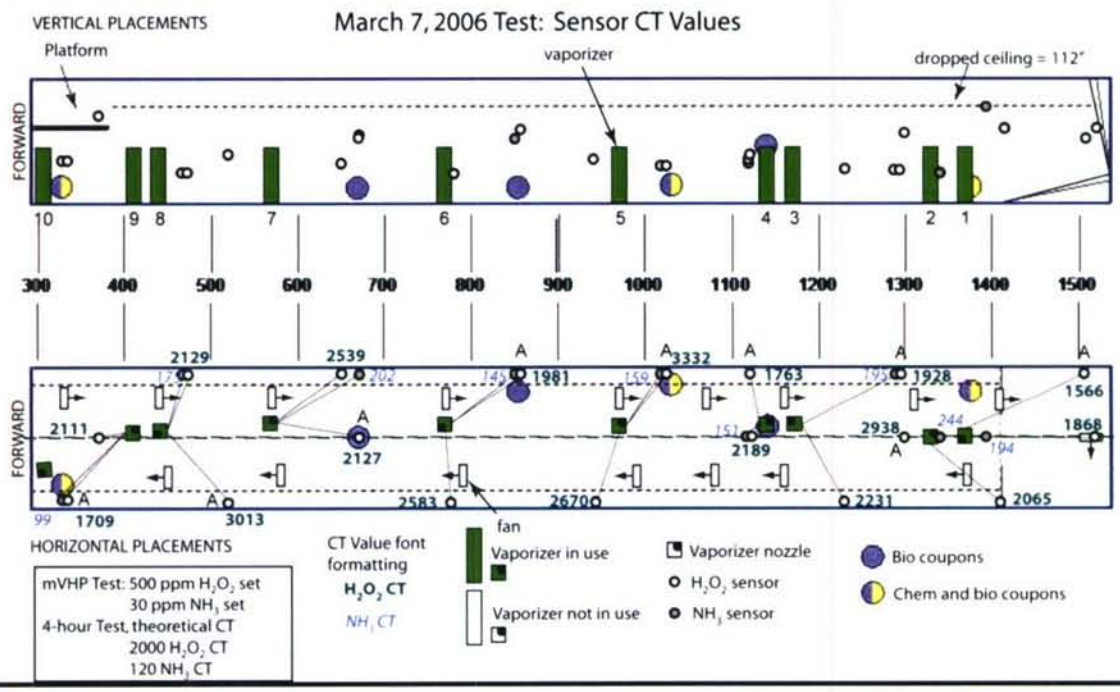
3.6.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) were provided in Table 3.6.2.1. The decontamination time for this test was 4 hr. The entire cycle time of this test was 8 hr and 42 min. The average CT for all 18 hydrogen peroxide sensors was 2225 ppm-hr. The average CT for ammonia for all 9 sensors was 170 ppm-hr. The target CTs for hydrogen peroxide and ammonia were 2000 and 120 ppm-hr, respectively. The values recorded in Table 3.6.2.1 are also shown in Figure 3.6.2.

Table 3.6.2.1: 3/7/06 CT readings for each Vaporizer (ppm-hr)

Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	1565.62	1868.21	194.19
2	2938.33	2064.98	243.86
3	1928.02	2231.63	195.43
4	1762.78	2189.23	151.05
5	3331.71	2669.52	159.43
6	1981.38	2583.19	144.94
7	2126.55	2539.12	202.21
8	3013.13	2128.93	174.64
9	1709.43	2110.74	99.27

Figure 3.6.2: Sensor CT Values - Mar. 7th



3.6.3 BI Results.

One hundred Apex (ATCC 12980, Lot H2165 Exp. 31 March 06) and 100 Steris (ATCC 7953, Lot 0306 Exp. 30 Oct 06, 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to 7 days. All Apex BIs were negative for growth except 14, 15, 17, 18, 19, 20, 33, 54, 63, 72, 84, 87, and 94, which were positive for growth each day following testing. All Steris BIs were negative for growth. Figure 3.6.3 diagrams locations of all BIs used during the March 7 test.

3.6.4 Biological Coupon Results

As mentioned in Section 2.9, four biological coupons of each of the three functional materials (glass, aluminum, CARC) was prepared and deposited into the aircraft for the test. Coupon locations were outlined in Table 2.9.1.

Coupons were placed in each of the seven locations for a total of 84 coupons. A coupon of each material type and from each location was placed in broth. Only samples showing growth in the broth treatment were plated. All coupons showed no growth.

Figure 3.6.4 indicates that no growth was observed for any location or functional material. The three control samples prepared on February 27th showed average growth for 1.52E6 on glass, 2.64E5 on CARC, and 2.27E4 on aluminum.

Figure 3.6.3: BI Results - Mar. 7th

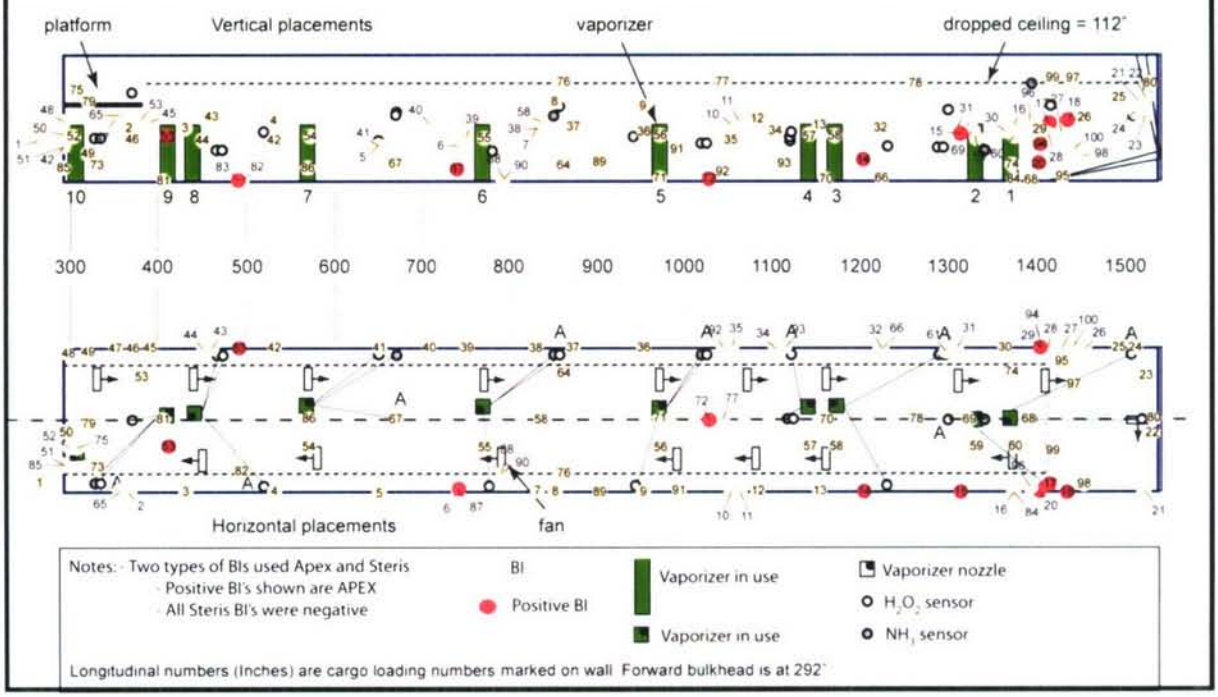
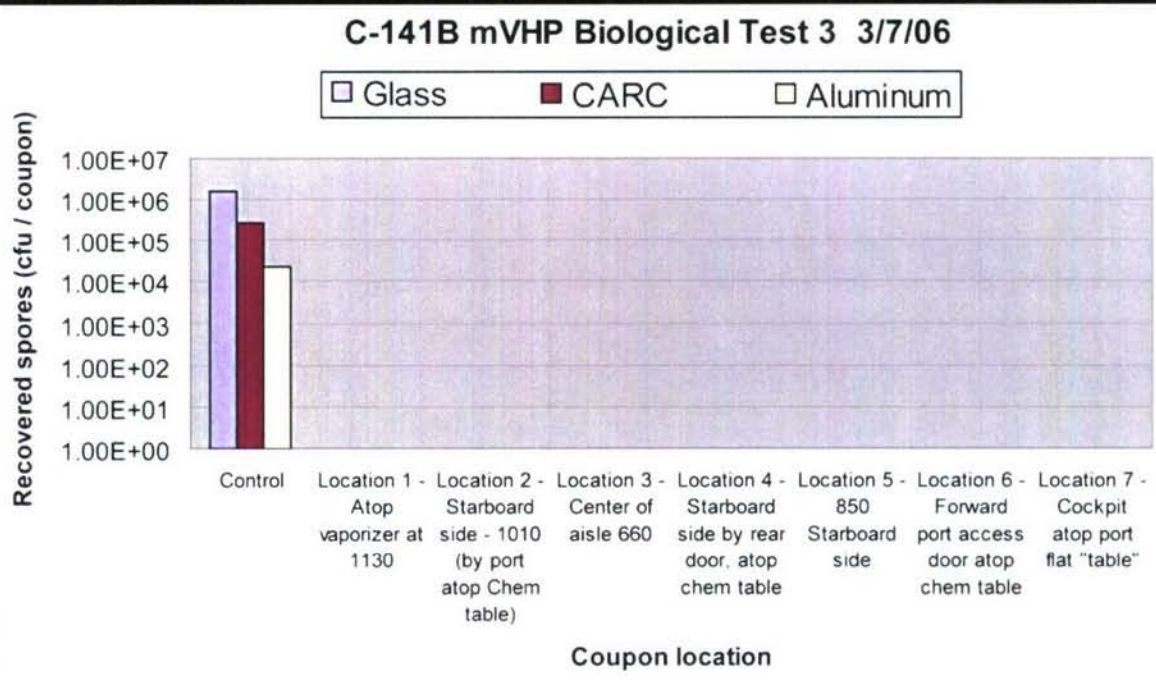


Figure 3.6.4: Biological Coupon Results - Mar. 7th



3.6.5 Chemical Coupon Results.

3.6.5.1 Vapor Analysis of Headspace.

The results of the CEPS vapor analysis from the March 7 test were included in Table 3.6.5.1. The aircraft (A/C) locations correspond to the descriptions from Section 2.12. The mass of the CEPS measured by the GC and the mass/volume concentration, calculated from the measured total volume of air flow over the sample, were included in the final two columns. The JPID threshold and objective values were 0.0058 $mg/m^3$and 0.003 mg/m^3, respectively. Comparing the mass/volume concentration of CEPS, the remaining CEPS levels were below the JPID threshold and objective values.

Table 3.6.5.1: March 7 Vapor Analysis Results

Surface	A/C Location	CEPS, ng/coupon	CEPS mg/m3
Aluminum	Forward	1.00	0.0001
Aluminum	Forward	1.00	0.0001
Aluminum	Forward	1.00	0.0001
Aluminum	Forward	1.00	0.0001
CARC	Forward	18.96	0.0016
CARC	Forward	16.70	0.0014
CARC	Forward	14.22	0.0012
CARC	Forward	22.12	0.0018
Aluminum	Amidships	10.95	0.0009
Aluminum	Amidships	1.00	0.0001
Aluminum	Amidships	1	0.0001
Aluminum	Amidships	1.00	0.0001
CARC	Amidships	78.50	0.0065
CARC	Amidships	83.79	0.0070
CARC	Amidships	76.06	0.0063
CARC	Amidships	13.50	0.0011
Aluminum	Rear	1.00	0.0001
Aluminum	Rear	1.00	0.0001
Aluminum	Rear	11.27	0.0009
Aluminum	Rear	1.00	0.0001
CARC	Rear	82.88	0.0069
CARC	Rear	74.05	0.0062
CARC	Rear	106.56	0.0089
CARC	Rear	73.16	0.0061

3.6.5.2 Contact Exposure Analysis.

The contact exposure results from the March 7 test were listed in Table 3.6.5.2. The 15-min contact time represents the amount of time the latex was in contact with the contaminated side of the test coupon. Similarly, the 45-min contact time represents a second piece of latex inserted following the 15-min contact period, which permitted a total contact time of 60 min. All of the 15-min samples had recoverable CEPS. The analytical values reported in Table 3.6.5.2 are below the method calibration low-standard so the accuracy of these numbers is not known. Based on the results, the March 7th test shows the potential to meet the JPID ORD threshold requirements; however, the analytical results cannot be validated.

Table 3.6.5.2: March 7 Contact Analysis Results

Surface	Contact Time, min	A/C Location	CEPS, ng/uL*	CEPS, ng/coupon	CEPS, mg/m2	Surface	Contact Time, min	A/C Location	CEPS, ng/uL*	CEPS, ng/coupon	CEPS, mg/m2
Aluminum	15	Forward	0.5200	5200	2.56	Aluminum	45	Forward	ND	0	0.00
Aluminum	15	Forward	0.5160	5160	2.54	Aluminum	45	Forward	ND	0	0.00
Aluminum	15	Forward	0.5710	5710	2.81	Aluminum	45	Forward	ND	0	0.00
Aluminum	15	Forward	0.5340	5340	2.63	Aluminum	45	Forward	ND	0	0.00
CARC	15	Forward	0.5700	5700	2.81	CARC	45	Forward	ND	0	0.00
CARC	15	Forward	0.5340	5340	2.63	CARC	45	Forward	ND	0	0.00
CARC	15	Forward	0.5360	5360	2.64	CARC	45	Forward	ND	0	0.00
CARC	15	Forward	0.5080	5080	2.50	CARC	45	Forward	ND	0	0.00
Aluminum	15	Amidships	0.5310	5310	2.62	Aluminum	45	Amidships	ND	0	0.00
Aluminum	15	Amidships	0.5480	5480	2.70	Aluminum	45	Amidships	ND	0	0.00
Aluminum	15	Amidships	0.5800	5800	2.86	Aluminum	45	Amidships	ND	0	0.00
Aluminum	15	Amidships	0.5230	5230	2.58	Aluminum	45	Amidships	ND	0	0.00
CARC	15	Amidships	0.6220	6220	3.06	CARC	45	Amidships	0.9260	9260	4.56
CARC	15	Amidships	0.5560	5560	2.74	CARC	45	Amidships	0.5190	5190	2.56
CARC	15	Amidships	0.5330	5330	2.63	CARC	45	Amidships	ND	0	0.00
CARC	15	Amidships	0.5360	5360	2.64	CARC	45	Amidships	ND	0	0.00
Aluminum	15	Rear	0.5670	5670	2.79	Aluminum	45	Rear	ND	0	0.00
Aluminum	15	Rear	0.5720	5720	2.82	Aluminum	45	Rear	ND	0	0.00
Aluminum	15	Rear	0.6400	6400	3.15	Aluminum	45	Rear	ND	0	0.00
Aluminum	15	Rear	0.5380	5380	2.65	Aluminum	45	Rear	ND	0	0.00
CARC	15	Rear	0.5710	5710	2.81	CARC	45	Rear	ND	0	0.00
CARC	15	Rear	0.7390	7390	3.64	CARC	45	Rear	ND	0	0.00
CARC	15	Rear	0.6840	6840	3.37	CARC	45	Rear	ND	0	0.00
CARC	15	Rear	0.5050	5050	2.49	CARC	45	Rear	ND	0	0.00

Results below 1.0 ng/uL are reported but are below calibrated limit

3.7 Test 6: 8 March 2006.

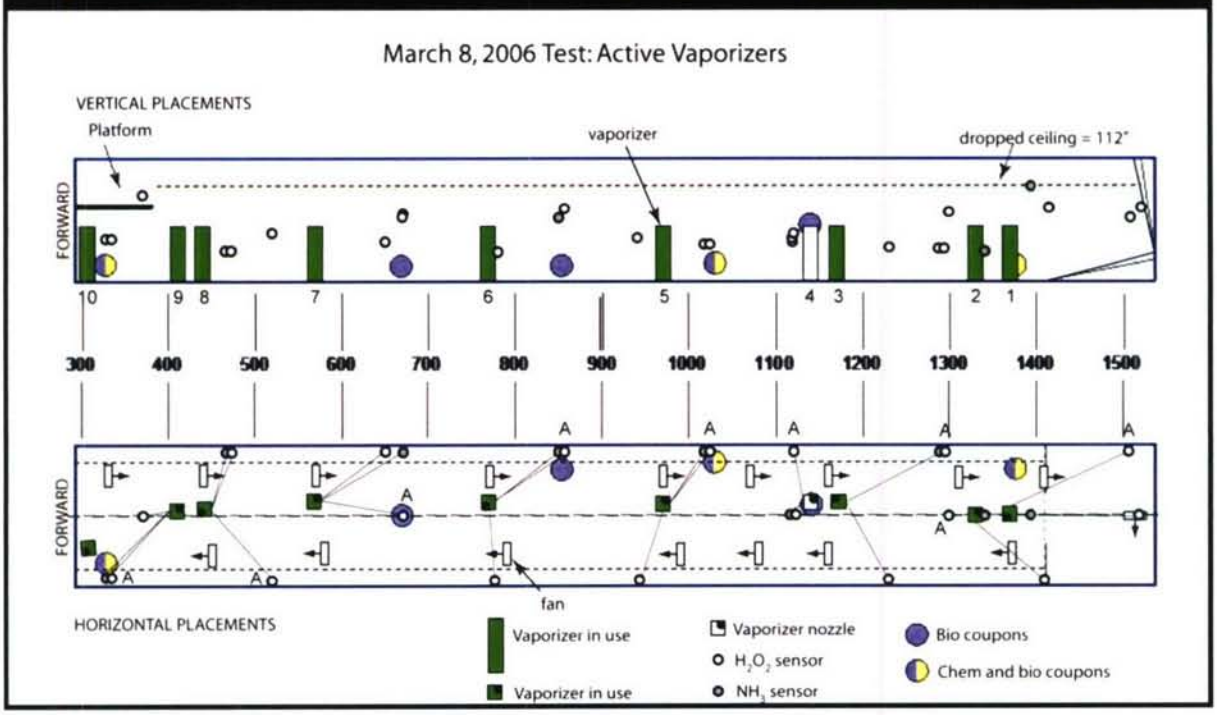
The 8 March 2006 test was an efficacy test employing VHP. Biological coupons, as well as biological indicators, were used to determine the efficacy of the test.

3.7.1 Operational Results.

The 8 March 2006 test was a 4-hr decontamination test using 500-ppm hydrogen peroxide (VHP). The test utilized every vaporizer, with the exception of vaporizer 4. Note that vaporizer 10 provided fumigant to the cockpit area only. Since this vaporizer did not contribute

to the cargo area concentration, and due to a sampling time discrepancy to be discussed later, the vaporizer was not used in the calculation for cycle concentration. Figure 3.7.1 shows the locations of active vaporizers. The average temperature and RH in the cargo bay were 29.91 °C ± 0.51 and 25.11% ± 0.59, respectively.

Figure 3.7.1: Active Vaporizers - Mar. 8th

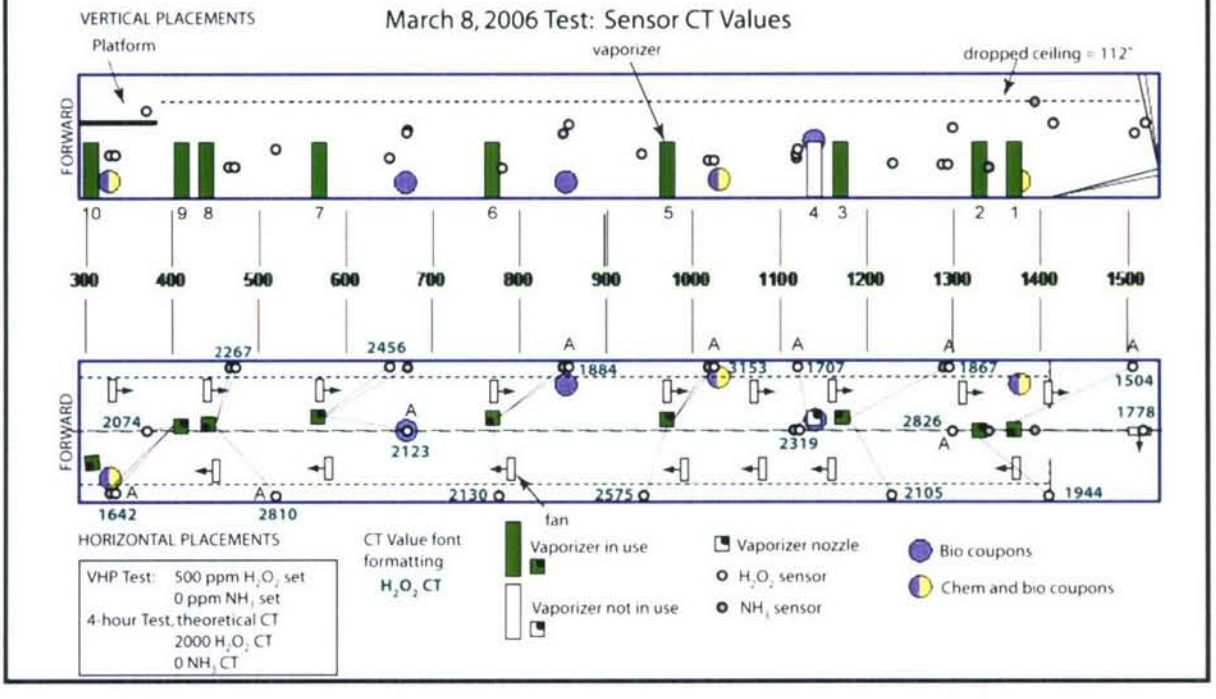


3.7.2 CT Results.

The CT results for each vaporizer for the complete decontamination cycle (i.e., power up to power off) were provided in Table 3.7.2.1. The decontamination time for this test was 4 hr. The entire cycle time of this test was 8 hr and 26 min. The average CT for all 18 hydrogen peroxide sensors was 2176 ppm-hr. Although no ammonia was introduced in this test, an average CT of 26 ppm-hr for the 9 sensors was observed. The target CT for hydrogen peroxide was 2000 ppm-hr. The values recorded in Table 3.7.2.1 are also shown in Figure 3.7.2.

Table 3.7.2.1: 3/8/06 CT readings for each Vaporizer (ppm-hr)			
Vaporizer	H2O2 CT A	H2O2 CT B	NH3 CT
1	1503.53	1777.91	37.36
2	2826.32	1944.16	49.85
3	1866.94	2104.81	43.75
4	1707.44	2319.20	0.00
5	3152.63	2574.39	18.83
6	1883.63	2130.03	16.88
7	2122.97	2456.27	32.63
8	2810.08	2267.21	20.02
9	1641.67	2074.20	11.84
10	2280.39	1483.53	25.54

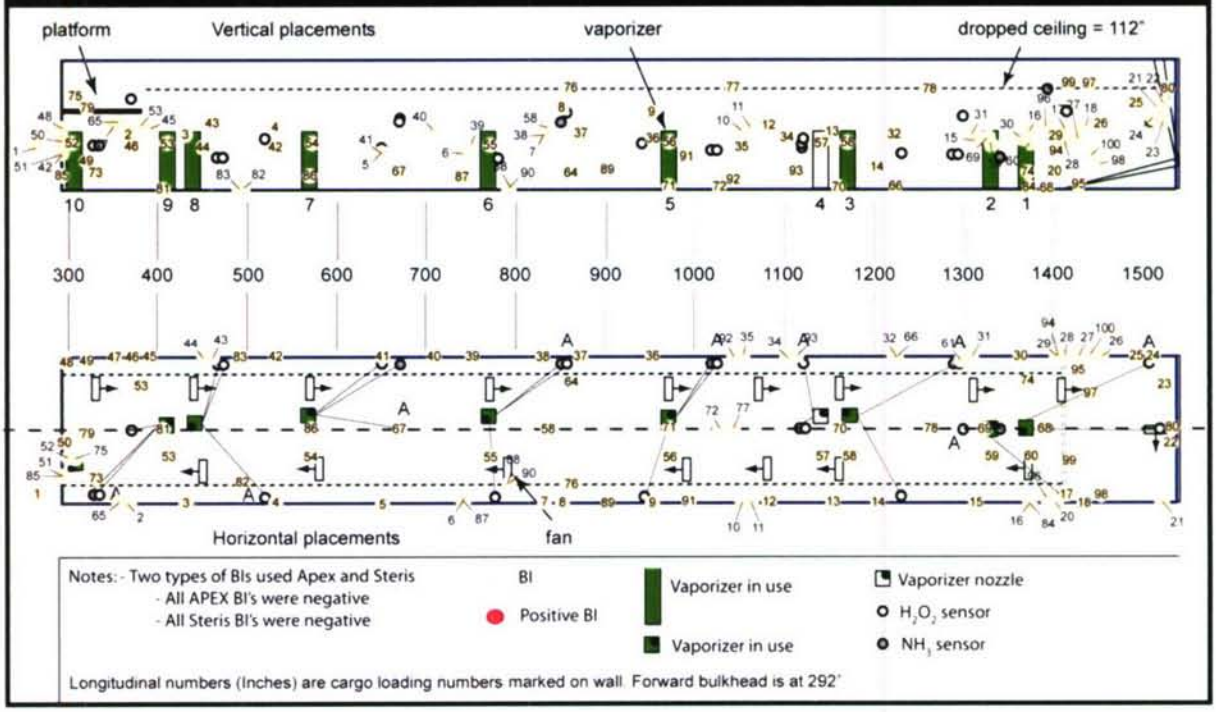
Figure 3.7.2: Sensor CT Values - Mar. 8th



3.7.3 BI Results.

One hundred Apex (ATCC 12980, Lot H2165 Exp. 31 March 06) and 100 Steris (ATCC 12980, Lot H3355 Exp. 31 Jul 06, 7953, Lot 0306 Exp. 30 Oct 06, 06) BIs were distributed throughout the C-141 aircraft. The locations were denoted in Table 2.10. Each location had one Apex and one Steris BI. BIs were examined for growth each day following the test up to 7 days. All BIs were negative for growth. Figure 3.7.3 diagrams locations of all BIs used during the March 8 test.

Figure 3.7.3: BI Results - Mar. 8th



3.7.4 Biological Coupon Results.

As mentioned in Section 2.9, four biological coupons of each of the three functional materials (glass, aluminum, CARC) was prepared and deposited into the aircraft for the test. Coupon locations were outlined in Table 2.9.1.

Coupons were placed in each of the seven locations for a total of 84 coupons. A coupon of each material type and from each location was placed in broth. Only samples showing growth in the broth treatment were plated. All coupons showed no growth.

Figure 3.7.4: Biological Coupon Results - Mar. 8th

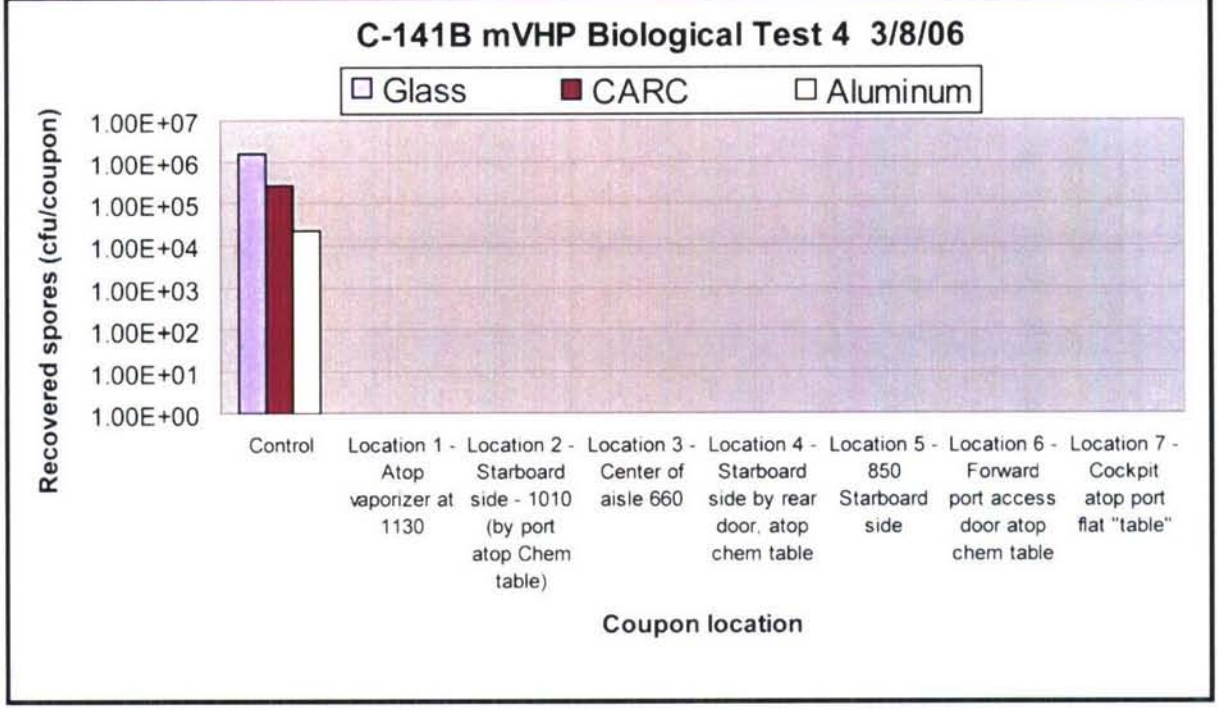
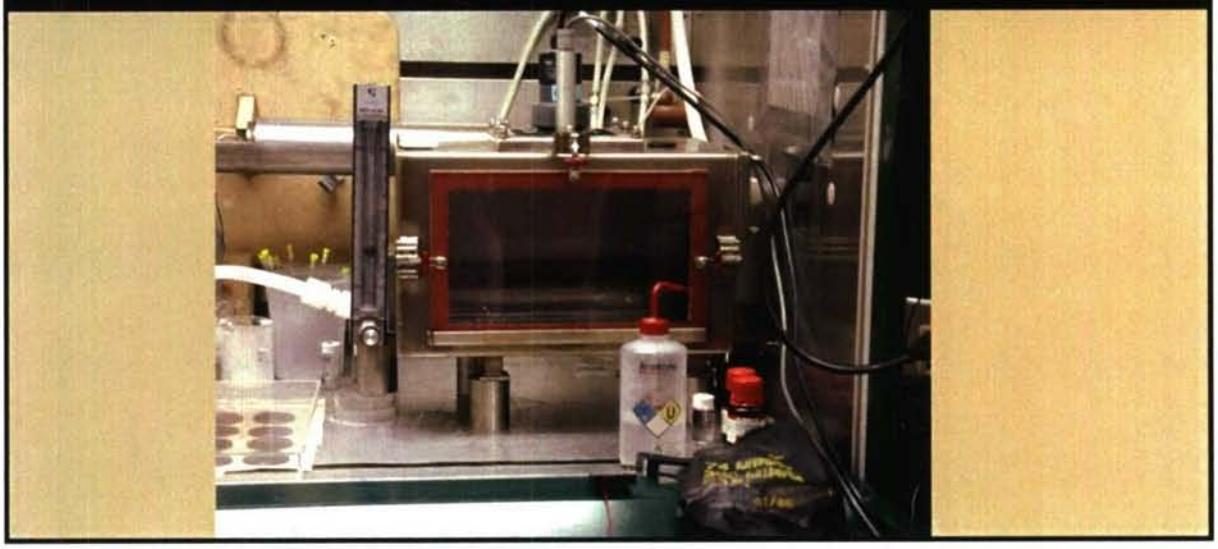


Figure 3.7.4 above indicates that no growth was observed for any location or functional material. The three control samples prepared on February 27th showed average growth for 1.52E6 on glass, 2.64E5 on CARC, and 2.27E4 on aluminum.

3.8 CEPS - HD Preliminary Correlation Study.

Aluminum and CARC coupons were spiked with both HD and HD-surrogate CEPS with 0.5-uL drops to achieve a 1.0 g/m^2 contamination density, similar to the procedure outlined in Section 2.12. The coupons were allowed to stand covered for 60 min and then inserted into a small chamber and subjected to 500-ppm VHP (hydrogen peroxide only). A picture of the chamber is shown in Figure 3.8.1. Its approximate volume was 0.025 m^3. At various time intervals, coupons were removed for vapor analysis. The objective was to compare the reduction of HD and CEPS from the two test surfaces during equivalent VHP fumigation. The results from the HD/CEPS correlation study are shown in Figure 3.8.2. This study was not rigorous and only addressed the vapor-hazard not the contact-hazard. Since the test was conducted, the data are worth showing. CEPS was more persistent under the described conditions then HD on bare aluminum and CARC paint.

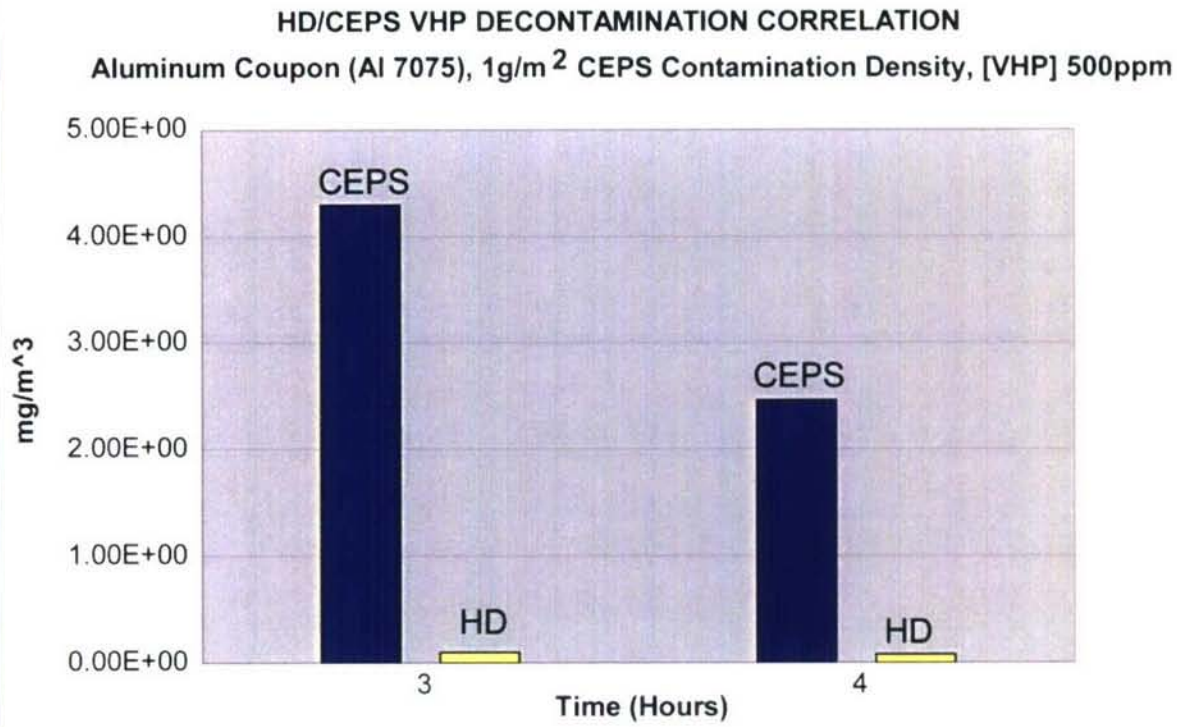
Figure 3.8.1: Small Test Chamber



3.9 CEPS - Preliminary Evaporative Loss (Baseline) Study.

Evaporative loss, or the amount of CEPS that was removed from a surface and was not a result of the hydrogen peroxide and/or ammonia, was attempted on March 6 within the C141. Aluminum and CARC coupons were spiked with CEPS following the same procedures identified in Section 2.12. Inserting the coupons into the aircraft at the amidships position, the MTV system was run without injecting hydrogen peroxide or ammonia into the intake. This created a condition within the aircraft similar to any other decontamination operation; turbulent air flow and elevated temperature, without the benefit provided from hydrogen peroxide. At 60, 120, and 150 min, coupons were removed in duplicate from the C141 and immediately inserted into a vapor can for analysis. Each coupon was analyzed for 60 min with a conditioned air flow of 200 ml/min. The results, reported as mass per volume are listed in Table 3.9. Due to equipment problems, the test was stopped after 150 min. A control time 0 sample was not tested to determine the vapor just after contamination so the % reduction for the baseline test cannot be determined. In addition, contact data was not measured to determine surface CEPS concentrations. The test was not conducted for the entire duration period of 4- to 5-hr. The data are provided for completeness of the activities conducted during the C141 evaluation. The results of this test are used for the MTV system evaluation.

Figure 3.8.2: Preliminary CEPS - HD Correlation



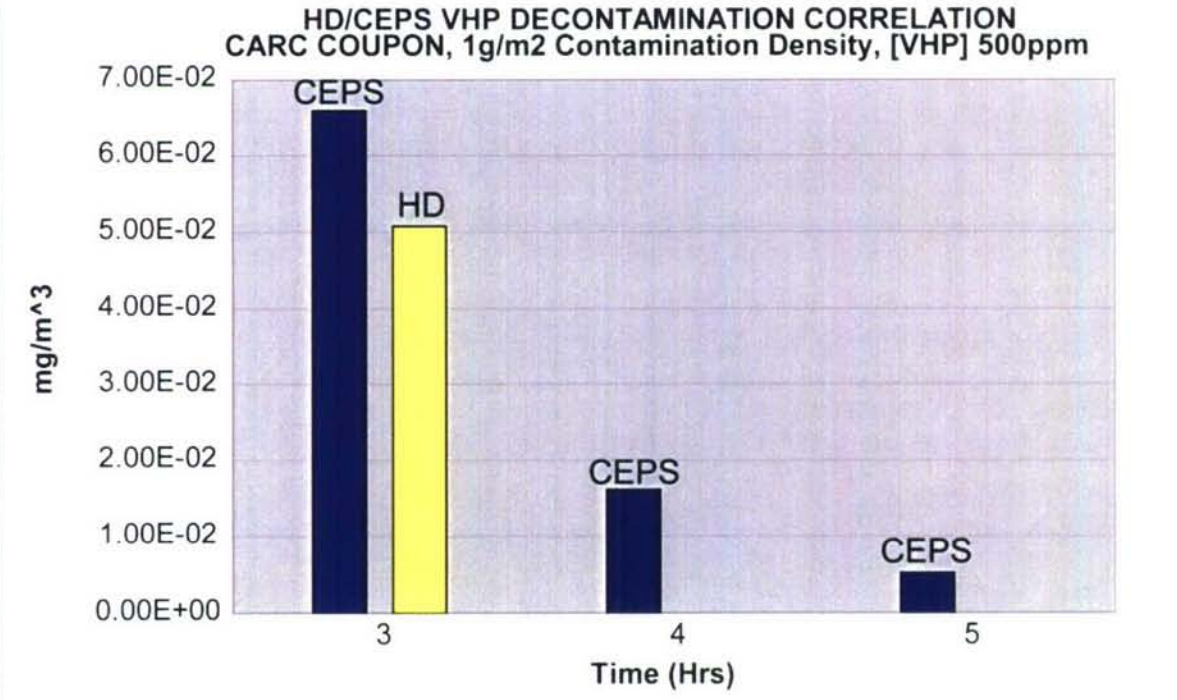


Table 3.9: Evaporative Loss Data								
Time	Surface	CEPS [mg/m3]	Time	Surface	CEPS [mg/m3]	Time	Surface	CEPS [mg/m3]
60	Aluminum	0.0149	120	Aluminum	0.0493	150	Aluminum	0.0143
60	Aluminum	0.0156	120	Aluminum	0.0156	150	Aluminum	0.0143
60	CARC	0.0122	120	CARC	0.0116	150	CARC	0.0115
60	CARC	0.0132	120	CARC	0.012	150	CARC	0.0107

4. DISCUSSION

4.1 Operational Discussion.

4.1.1 Generator Operation.

The evaluation was for the FMTV prototype. The first two tests only used half of the vaporizers. The latter four tests used at least nine of the vaporizers with the March 7th test using all ten vaporizers. The number of vaporizers was based on the size of the space. The injection rate information was not available to compare the injection needs for running half versus all vaporizers to reach target concentration. The fumigant distribution tracked location somewhat. The CT was lowest at the rear of the aircraft and greatest in the middle toward the cockpit. The mVHP system demonstrated the ability to reach target treatment concentrations in a simulated operational environment.

4.1.2 Average Temperature and RH Discussion.

The mVHP system was able to effectively warm the cargo bay interior to achieve treatment temperatures in the range of 30 °C (86 °F) to 41 °C (106 °F). In addition, the system was able to sufficiently dry the cargo bay interior to less than 20% RH when outside RH reached as high as 67 – 76% on days averaging 41 – 50%. The mVHP system demonstrated the ability to reach target process conditions when the exterior humidity was high (Tables 4.1.2.1 and 4.1.2.2).

Table 4.1.2.1: Average Temperature (°C)						
Sensor	**2/27/2006**	**2/28/2006**	**3/2/2006**	**3/3/2006**	**3/7/2006**	**3/8/2006**
Sensor 1	41.09	37.49	35.58	32.04	30.87	29.99
Sensor 2	41.17	37.60	30.95	30.76	30.73	29.32
Sensor 3	41.25	39.11	36.36	33.18	34.44	29.75
Sensor 4	41.64	38.53	35.97	32.72	34.13	29.40
Sensor 5	41.00	38.56	35.33	32.76	34.31	29.66
Sensor 6	41.23	38.64	35.36	32.98	34.56	29.58
Sensor 7	41.56	38.77	35.42	33.43	34.71	30.14
Sensor 8	41.75	40.08	37.20	34.32	35.35	30.80
Sensor 9	41.86	39.66	36.90	33.99	35.21	30.56
Average	41.39	38.72	35.45	32.91	33.81	29.91
St. Dev.	0.31	0.85	1.82	1.06	1.75	0.51
Day. Max	81	81	68	79	73	61
Day. Ave.	63	68	60	62	65	53

4.1.3 CT Discussion.

The controlling hydrogen peroxide sensors ("A") were mostly placed closer to the walls of the C141; whereas, the secondary hydrogen peroxide sensors ("B") were along the center of the aircraft. In general, sensor 1 closest to the back end of the aircraft showed the lowest concentration. Sensors 5 and 8 typically showed the highest concentration. The CTs in general were closer in range for the "B" sensor locations compared to the "A" locations. A detailed analysis of the CTs was not conducted to determine the relationships between number of vaporizers, injection rates or test length.

The injection rate information was not available to compare the injection needs for the system for half versus all vaporizers. In general, a 500-ppm hydrogen peroxide and 30-ppm ammonia mVHP concentration were achieved in a large venue such as the C141.

4.2 BI Discussion.

In general, for the 4-5-hr tests, BI survivors were in the rear of the aircraft closest to the door and vaporizer #1. This region typically had the lowest concentration, which was expected considering the location.

The 2-3-hr run length was not sufficient for rendering all the BIs nonviable. After the first two tests, questions were raised about the difference between Steris and Apex BIs. The first two tests showed positive returns for most of the Apex BIs and mostly negative returns for the Steris BIs. A laboratory analysis showed that the Apex spores were a bit more resistant at lower treatment durations (Table 4.2); however, once a minimum 40-min exposure was achieved in the D-box, the response was the same. These early tests did not use all of the vaporizers

compared to the later tests. Although the decontamination phase concentrations were reasonable, the data might suggest that by using fewer vaporizers, the mVHP fumigant effectiveness diminishes over distance. There was no definitive proof to explain the February 27th and 28th BI survivors.

Table 4.1.2.2: Average Relative Humidity (%RH)

Sensor	2/27/2006	2/28/2006	3/2/2006	3/3/2006	3/7/2006	3/8/2006
Sensor 1	6.03	9.24	17.26	19.71	16.99	24.60
Sensor 2	6.61	9.69	23.70	20.18	17.54	25.54
Sensor 3	5.85	8.75	15.80	18.63	19.55	24.75
Sensor 4	6.35	9.64	17.39	19.99	20.52	26.16
Sensor 5	6.07	9.08	17.32	19.45	19.72	25.12
Sensor 6	6.02	9.18	17.14	19.11	19.19	24.95
Sensor 7	6.44	9.63	17.90	19.46	19.87	25.21
Sensor 8	6.12	8.89	16.41	18.87	19.14	24.14
Sensor 9	7.08	10.25	17.58	20.27	20.42	25.53
Average	6.29	9.37	17.83	19.52	19.22	25.11
St. Dev.	0.38	0.47	2.29	0.58	1.21	0.59
Day. Max	18	31	67	76	40	48
Day. Ave.	12	21	49	41	26	36

TABLE 4.2: BI Comparison Test

BI type and Lot number	Positive control	Negative control	10 min. exposure	20 min. exposure	30 min. exposure	40 min. exposure
Apex H2165	5/5 positive	5/5 negative	5/5 positive	3/5 positive	0/5 positive	0/5 positive
Steris 1885B	5/5 positive	5/5 negative	2/5 positive	1/5 positive	0/5 positive	0/5 positive
Apex H3355	5/5 positive	5/5 negative	1/5 positive	0/5 positive	0/5 positive	0/5 positive

The March 2nd, 3rd, and 8th tests used 8 to 9 of the cargo bay vaporizers. The BI response showed that most BIs were rendered non-viable with the occasional survivors in the aircraft rear nearest the cargo bay door. The March 7th test (test 5) shows the only discrepancy having 13 positive BIs in the rear. The reason for the additional survivors was not certain.

4.3 Biological Coupon Results.

The control coupon recoveries were not as tight was seen in other studies. The target loading was a minimum of 1×10^6 cfu/coupon to show a 6-log reduction in viable spores to meet ORD requirements. The glass samples showed a 1.5×10^6 cfu/coupon recovery. The CARC-coated samples showed a 2.6×10^5 cfu/coupon recovery. The aluminum samples showed a 2.3×10^4 cfu/coupon recovery. Since only one set of controls were performed, the low recovery may or may not be real. Conservative estimates of meeting ORD were made based on the controls. A definitive statement about the CARC-coated and bare aluminum results meeting ORD cannot be made from this test. However, prior tests have shown that a 6-log load, recovery and mVHP reduction was achievable.[14]

4.4 Chemical Coupon Results.

Complete baseline tests where samples were contaminated with CEPS and allowed to sit at ambient conditions were not conducted. Without baseline tests, the amount of CEPS loss due to evaporation cannot be fully determined; however, the live agent chambers tests saw minimal loss of HD during baseline tests and significant reductions in agent concentration during mVHP treatment.[8]

4.4.1 Vapor Analysis of Headspace.

The mass of the CEPS measured by the GC and the mass/volume concen-tration were calculated from the measured total volume of air flow over the sample. The CARC samples showed higher vapor values compared to base aluminum. All vapor levels for both chemical coupon tests were below the JPID threshold and objective values of 0.0058 mg/m^3 and 0.003 mg/m^3, respectively.

4.4.2 Contact Exposure Analysis.

The CARC-coated and aluminum sample tests for the February 28th contact-hazard analysis showed a mixture of recoveries and non-detects; whereas, the March 3rd test each coupon had some recoverable CEPS. The JPID threshold HD ORD was 3 mg/m^2. Simulant samples with measurable CEPS met this requirement. The difference between the February 28th and March 3rd test is not clear. The February 28th test had the fewest replicates than the March 3rd test, which limits the ability to test for outliers. The February 28th test had the better efficacy; however, the run length was 2-hr shorter and only five vaporizers were used. This result is confusing based on the March 3rd run, which had lower efficacy but was 2 hr longer and used eight vaporizers during the treatment. The source of the discrepancy is uncertain. The March 7th test shows the potential to meet ORD; however, the results were outside the calibrated limit, making a definitive conclusion not possible. However, the technology evaluated has shown the potential to meet ORD with longer treatment times. Optimization efforts to further increase operating temperatures and flow rates will probably be needed to achieve more uniform, process control-type decontamination results.

4.4.3 Simulant to Agent Comparison.

The relationship between CEPS and HD is not certain, so the projection for time required for HD decontamination is not known. Since CEPS is believed to be more persistent than HD, the time required for HD is expected to be less. The tests have demonstrated the ability to reduce HD-simulant contamination with the potential to meet ORD requirements on optimization.

4.5 Test Plan Execution.

Another major learning from this test was the growing need for a detailed test plan to manage field efforts of this magnitude. This effort did not have a detailed test plan to identify targets and goals, such as immediately investigating the low control recoveries for the biological coupons. Had the technical personnel on-site been informed that the target was to show a 6-log reduction, an on-the-spot retest could have been performed.

Blank

LITERATURE CITED

1. Jahnke, M.; Lauth, G. Biodecontamination of a Large Volume Filling Room with Hydrogen Peroxide. *Pharm. Eng.* **1997**, pp 2-12.

2. McDonnell, G.G.; Gringol, G.; Antloga, K. Vapor Phase Hydrogen Peroxide Decontamination of Food Contact Surfaces. *Dairy, Food Environ. Sanit.* **2002**, pp 868-873.

3. Wagner, G.; Sorrick, D.; Procell, L.; Brickhouse, M.D.; McVey, I.; Schwartz, L. Decontamination of VX, GD, and HD on a Surface Using Modified Vaporized Hydrogen Peroxide. *Langmuir* **2007**, *23,* pp 1178-1186.

4. Brickhouse, M.D.; Lalain, T.; MacIver, B.; Pfarr, J.; Procell, L.; Schultz, M.; Sorrick, D.; Turetsky, A.; Wagner, G.; Schwartz, L.; McVey, I.; Meilander, T.; Wiget, P. *The Development of Modified Vaporous Hydrogen Peroxide (mVHP) for Chemical and Biological Weapons Decontamination.* Presented at the Decon Conference, Tucson, AZ, 2005.

5. Brickhouse, M.D.; Turetsky, A.; MacIver, B.; Pfarr, J.; McVey, I.; Alter, W.; Lloyd, J.; Fonti, M. *Vaporous Hydrogen Peroxide (VHP) Decontamination of a C-141B Starlifter Aircraft Validation of VHP and Modified VHP (mVHP) Fumigation Decontamination Process via VHP-Sensor, Biological Indicator, and HD Simulant in a Large-Scale Environment;*. ECBC-TR-510; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2007.

6. Brickhouse, M.D.; Turetsky, A.; McVey, I. *Decontamination of CBW Agents by mVHP: Demonstration of the CBW Decontamination of a Building using mVHP;* ECBC-TR-470; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2007.

7. Lalain, T.; Brickhouse, M.D.; Gater, S.; Williams, K.; Hendershot, J.; Rodriguez, A.; Mantooth, B.; Stark, D. *Chemical-Warfare Agent Decontamination Efficacy Testing: Large-Scale Chamber mVHP Decontamination System Evaluation. Part I: Comparison to ORD*; ECBC-TR-527; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2007.

8. JRO. *Joint Platform Interior Decontamination (JPID) Operational Requirements Document (ORD)*, 2005.

9. McVey, I.; Schultz, M.; Centanni, M.; McDonnel, G. Activated Oxidizing Vapor Treatment System and Method. *USPTO App., US Patent 2004/0057868 A1,* 2004.

10. McVey, I.; Schwartz, L.; Centanni, M.; Wagner, G. Activated Vapor Treatment for Neutralizing Warfare Agents. *USPTO App., US Patent 2004/0215046 A1,* 2004.

11. Brickhouse, M.D.; Lalain, T.; MacIver, B.; Procell, L.; Schultz, M.; Sorrick, D.; Turetsky, A.; Pfarr, J.; Wagner, G.; Schwartz, L.; McVey, I.; Meilander, T.; Wiget, P. *The Development of Modified Vaporous Hydrogen Peroxide (mVHP) for Chemical and Biological Weapons Decontamination.* Presented at the CB Defense Conference, Timonium, MD, 2005.

12. JRO. *Operational Requirements Document for Joint Service Sensitive Equipment Decontamination* 2003.

13. Lalain, T.; Brickhouse, M.D.; Pfarr, J.; Gater, S.; Mantooth, B.; Stark, D. *Biological-Warfare Agent Decontamination Efficacy Testing: Large-Scale Chamber mVHP® Decontamination System Evaluation for Biological Contamination;* ECBC-TR- 521; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2007.

14. Lalain, T.; Brickhouse, M.D.; Pfarr, J.; Lloyd, J.; Flowers, J.; Mantooth, B.; Zander, Z.; Stark, D. *Evaluation of the Steris Sensitive Equipment Decontamination (SED) Apparatus on a 463L Pallet;* ECBC-TR-526; U.S. Army Edgewood Chemical Biological Center; Aberdeen Proving Ground, MD, 2007.

ACRONYMS AND ABBREVIATIONS

A/C	Aircraft
APG	Aberdeen Proving Grounds
BI	biological indicator
BSL	bio safety level
BW	biological warfare
CARC	Chemical Agent Resistant Coating
CASARM	chemical agent standard analytical reference material
CB	chemical and biological
CBW	chemical and Biological warfare
CCV	continuation calibration verification (CCV)
CEPS	Chloroethylphenyl sulfide
CFD	Computational Flow Dynamic
cfm	cubic feet minute
CFU, cfu	colony forming unit
CofA	certificate of analysis
CRADA	Cooperative Research and Development Agreement
CT	concentration time
CW	chemical warfare
DAAMS	depot area air monitoring system
DoD	Department of Defense
DS	Decontamination Sciences
ECBC	Edgewood Chemical Biological Center
FMTV	Family of Medium Tactical Vehicle
FPD	flame photometric detector
ft	feet
ft^3	cubic feet
GC	gas chromatograph
GD	nerve agent, soman
G. stearo	Shorthand for biological surrogate *G. stearothermophilus*
H2O2	hydrogen peroxide
HD	blister agent, mustard
HEPA	High Efficiency Particulate Air
hr	hour or hours
IAW	in accordance with
ICV	initial calibration verification
in.	inch or inches
IOP	Internal Operating Procedure
JPID	Joint Platform Interior Decontamination
JSSED	Joint Service Sensitive Equipment Decontamination
KPP	Key Performance Parameters
LOE	Limited-Objective Experiment
min	minutes
MSDS	Material Safety Data Sheets
MTV	Medium Tactical Vehicle

mVHP®, mVHP	reference to Steris' registered "modified vaporized hydrogen peroxide" procedure
ND	no detect
ORD	Operational Requirements Document
PEL	permissible exposure level
PI	principal investigator
PPE	personal protective equipment
ppm	parts per million
Pre-Op	pre-operational
psi	pounds per square inch
R&D	Research and Development
RDECOM	Research, Development, and Engineering Command (formerly SBCCOM)
RH	relative humidity
RRO	Risk Reduction Office
SBCCOM	Soldier and Biological Chemical Command
SD	standard deviation
SED	sensitive equipment decontamination
SOPs	standing operating procedures (standard may also be used in place of standing with the same meaning)
T, temp	temperature
t	time
TGD	nerve agent, thickened soman
TSA	Tryptic Soy Agar
TSB	Tryptic Soy Broth
SOR	start of run
TWA	time-weighted average
VHP®, VHP	reference to Steris' registered "vaporized hydrogen peroxide" procedure
VX	nerve agent

APPENDIX A

COUPON STOCK MATERIALS AND PREPARATION

Aluminum

- Type: 5052
- Supplier: E-J Enterprises
- Stock Material: received as 48 in. x 120 in. sheets, 0.125 in. thick
- Preparation Details: Biological surrogate tests (1.3-cm squares) and chemical coupons (2–in. disks) were punched at ECBC Fabrication shop.

Chemical Agent Resistant Coating (CARC)-painted Aluminum

- Type: Aluminum 5052, painted with Forest Green CARC, MIL-C-53039A
- Supplier: E-J Enterprises
- Stock Material: received as 48-in. x 120-in. sheets, 0.125 in. thick
- Preparation Details: Biological surrogate tests (1.3-cm squares) and chemical coupons (2-in.disks) were punched at ECBC Fabrication shop then painted on one face plus edges with Chemical Agent Resistant Coating, MIL-C-53039A, according to established procedures.

Blank

APPENDIX B

TEST CONTROL CHARTS

B.1 Control Charts for 27 February 2006

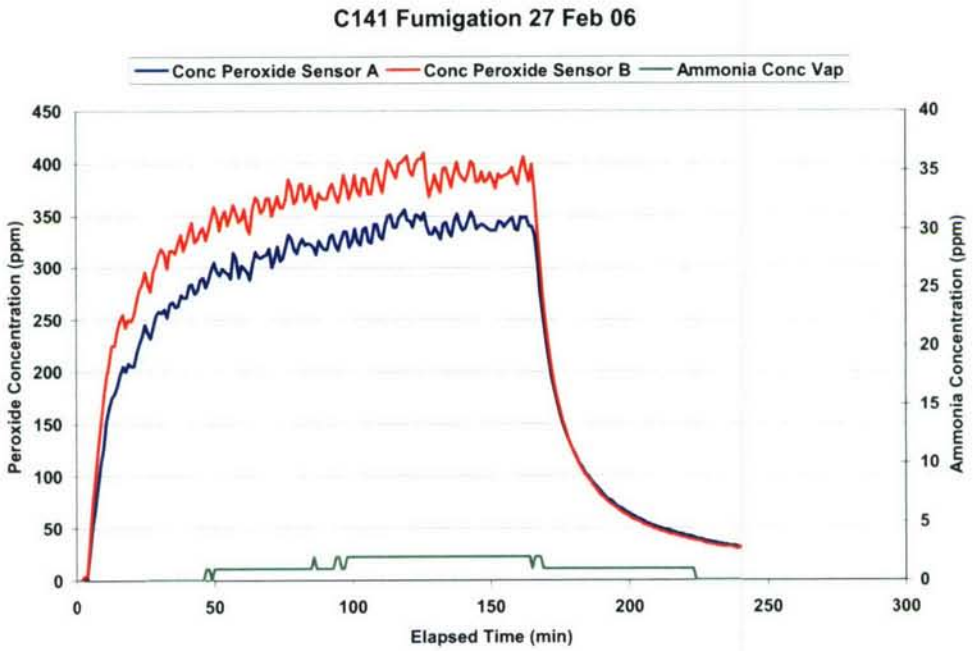


FIGURE B.1.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

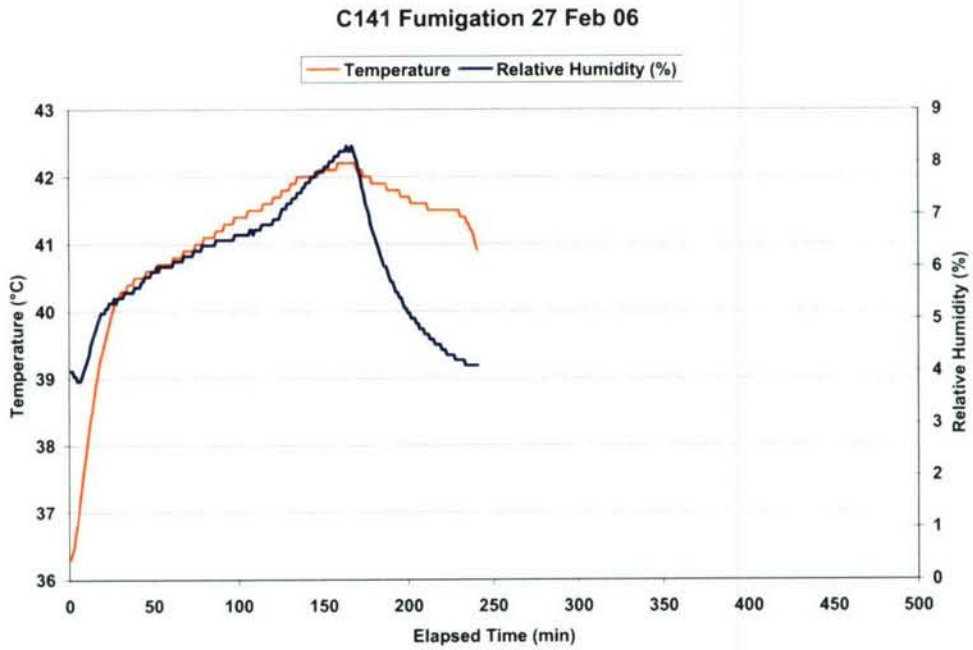


FIGURE B.1.1.2 WAS SENSOR 1, TEMP AND RH

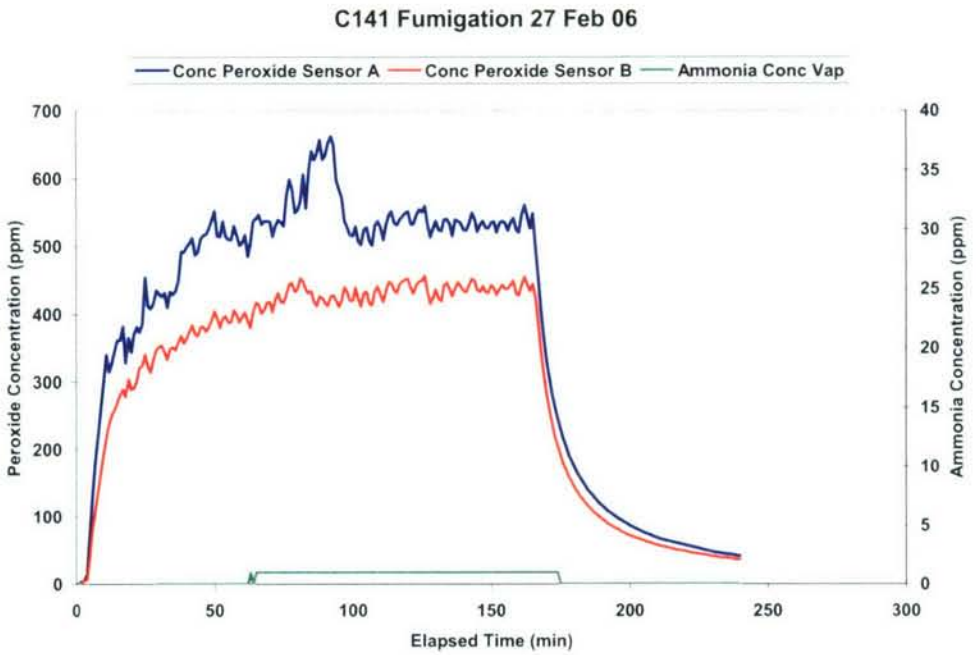


FIGURE B.1.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

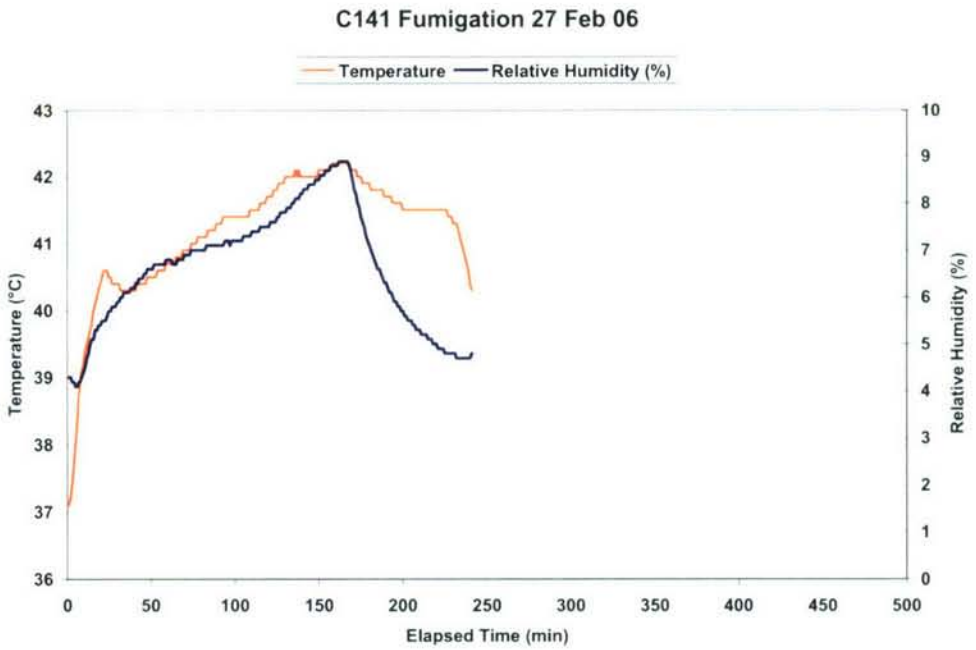


FIGURE B.1.2.2 WAS SENSOR 2, TEMP AND RH

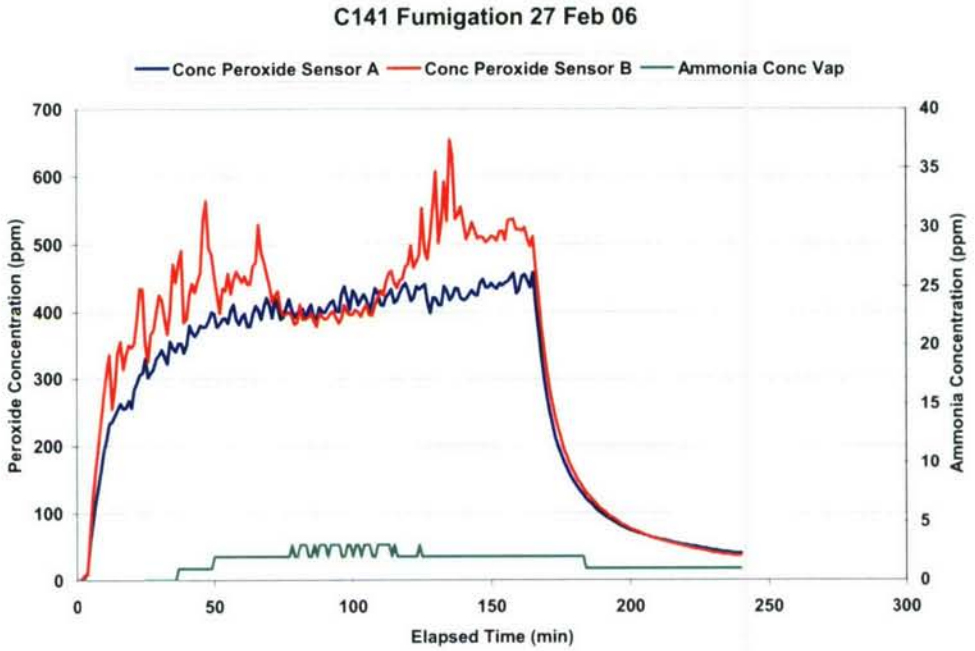


FIGURE B.1.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

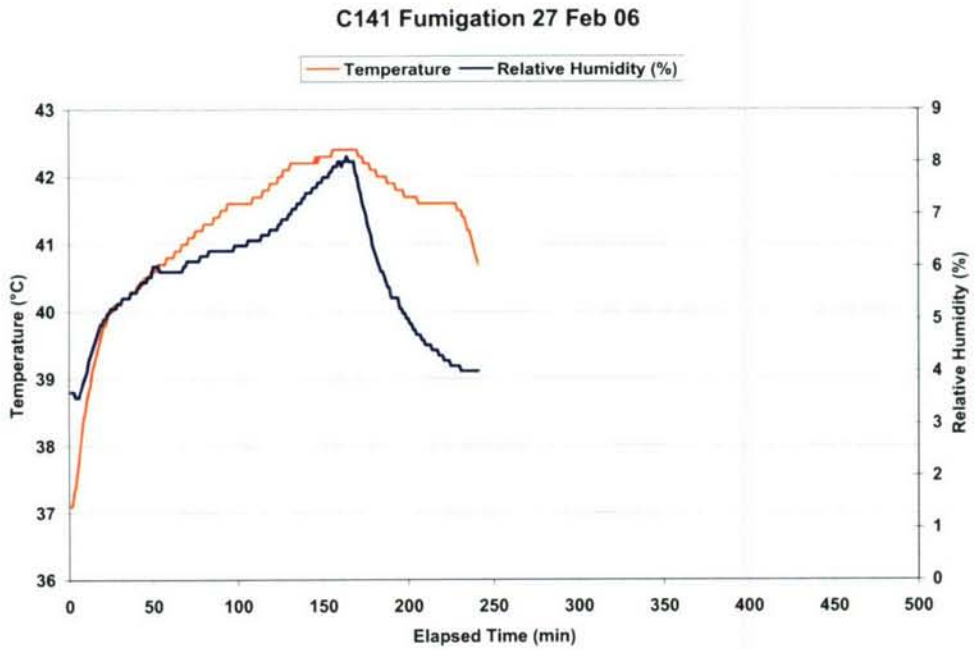


FIGURE B.1.3.2 WAS SENSOR 3, TEMP AND RH

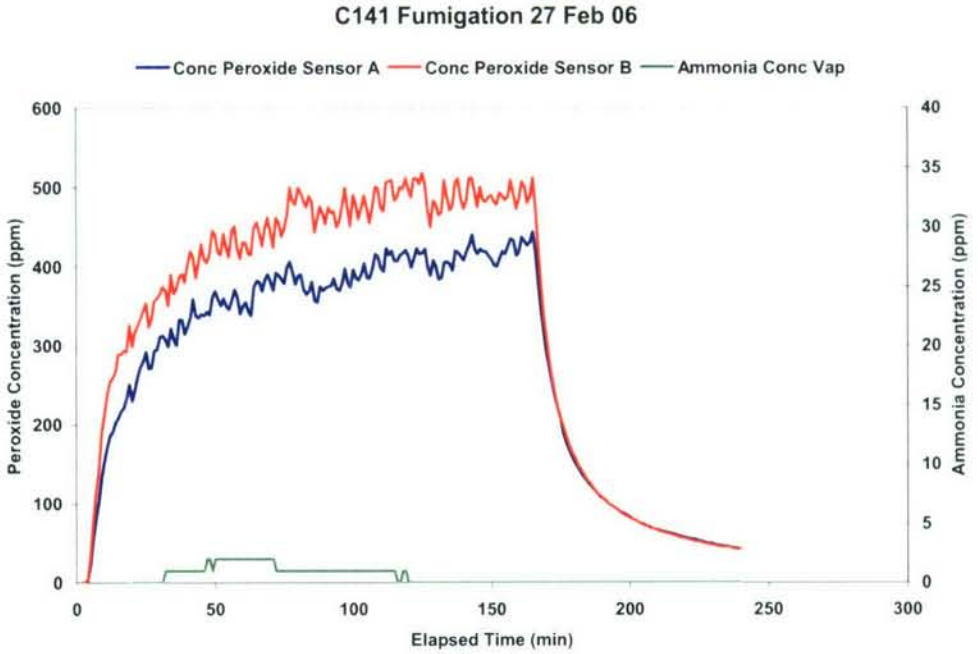


FIGURE B.1.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

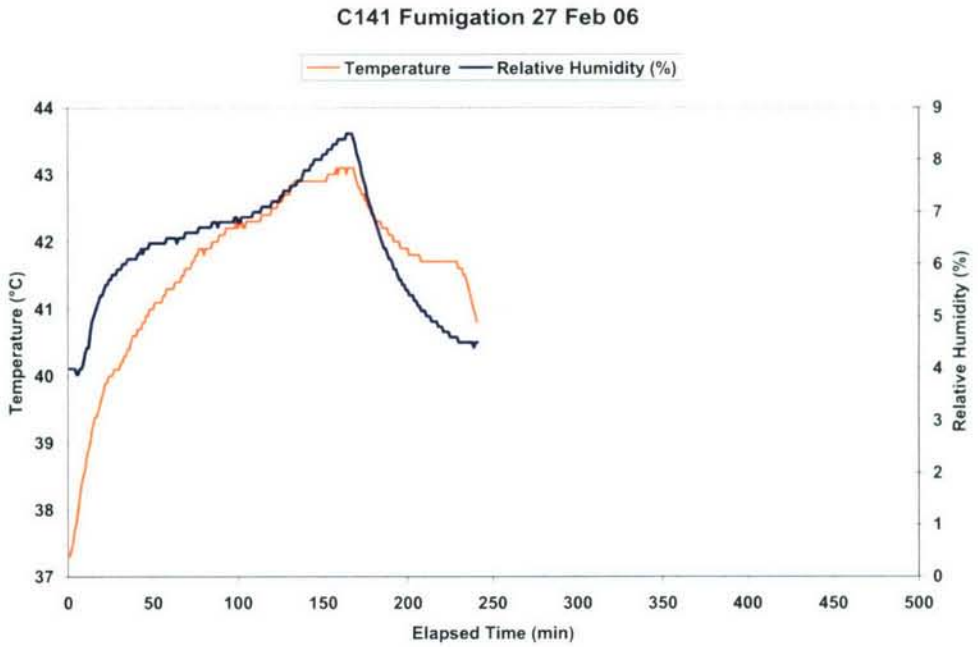


FIGURE B.1.4.2 WAS SENSOR 4, TEMP AND RH

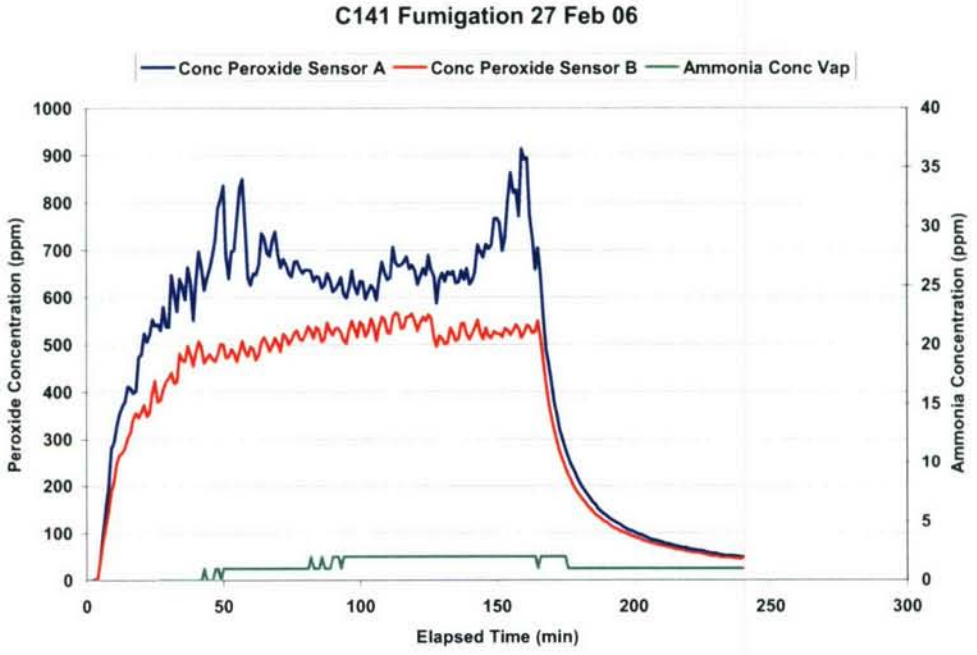


FIGURE B.1.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

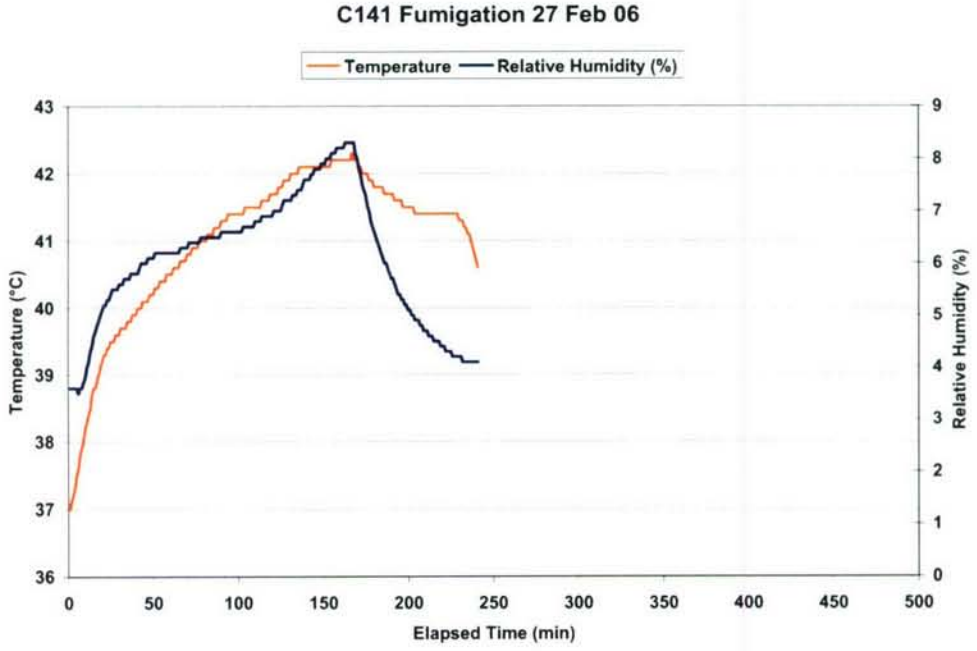


FIGURE B.1.5.2 WAS SENSOR 5, TEMP AND RH

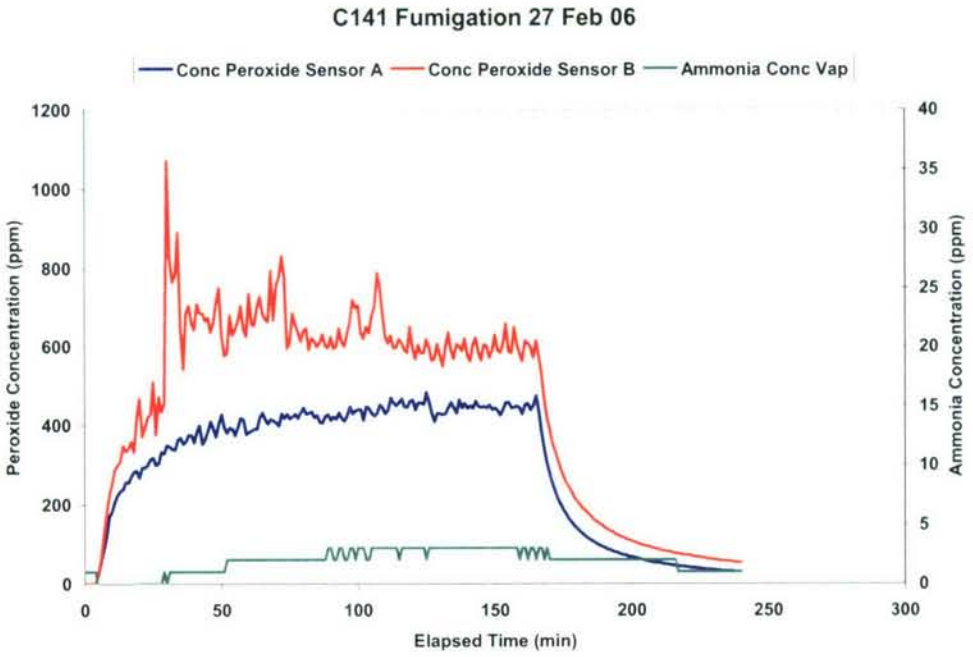


FIGURE B.1.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

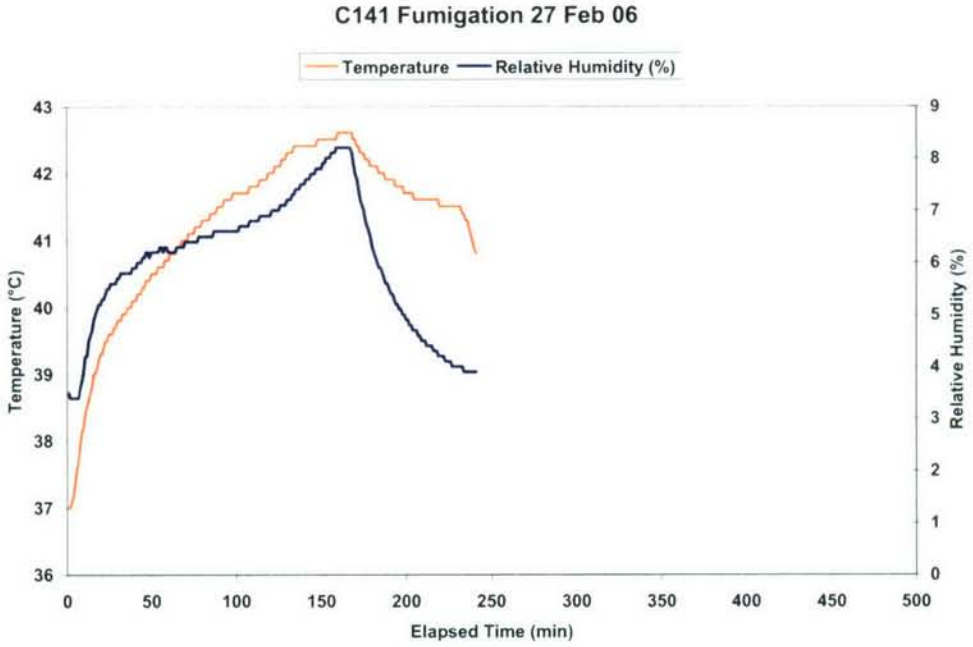


FIGURE B.1.6.2 WAS SENSOR 6, TEMP AND RH

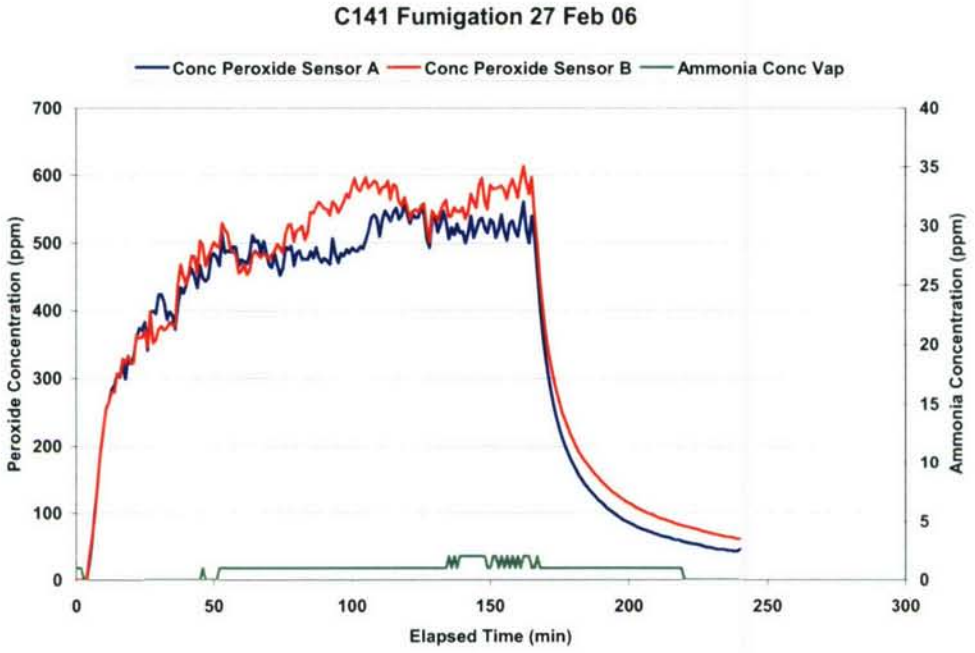


FIGURE B.1.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

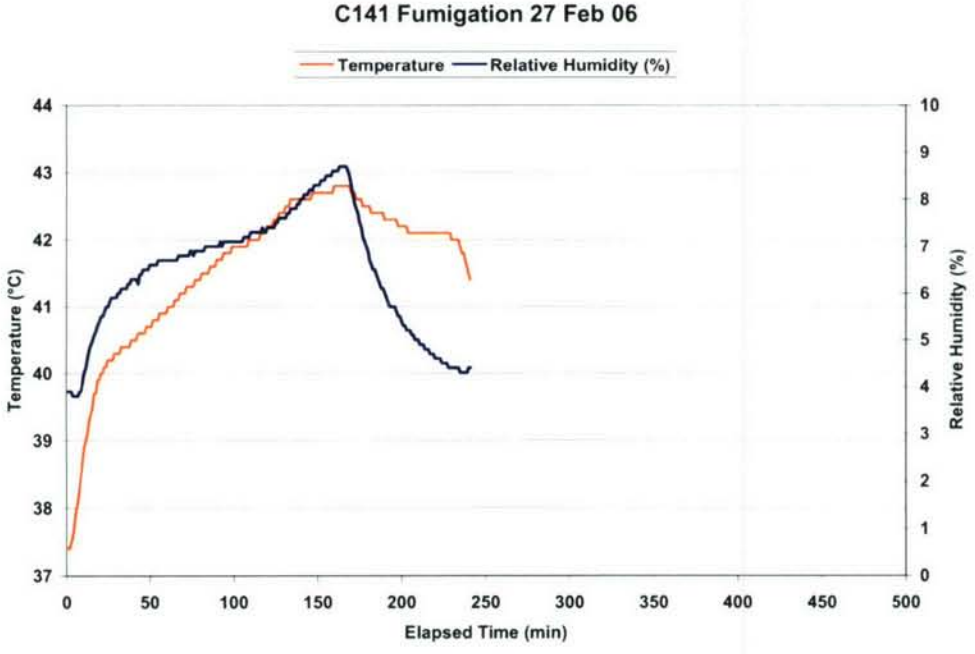


FIGURE B.1.7.2 WAS SENSOR 7, TEMP AND RH

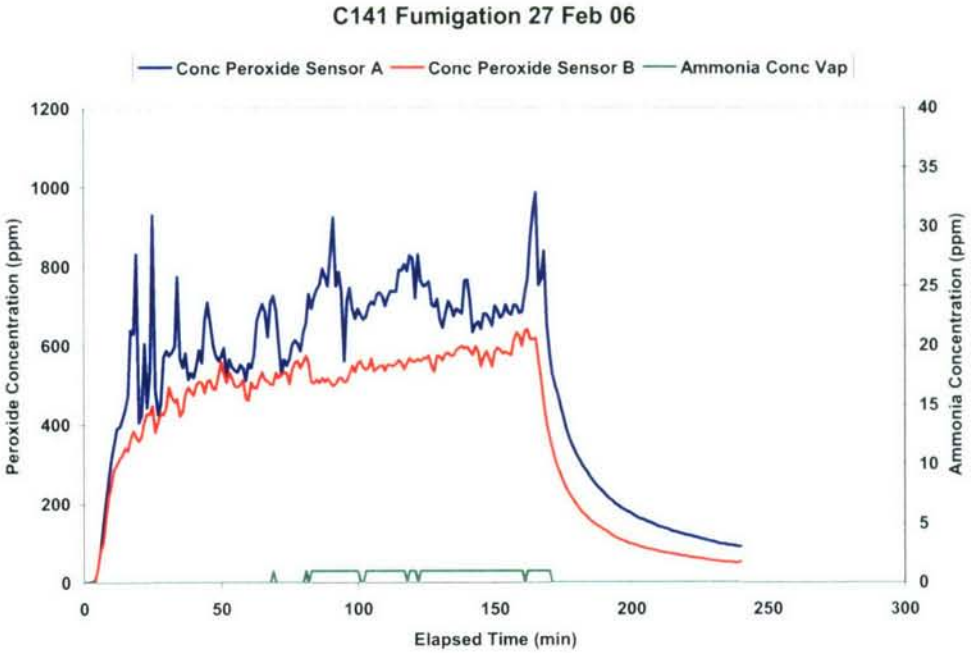


FIGURE B.1.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

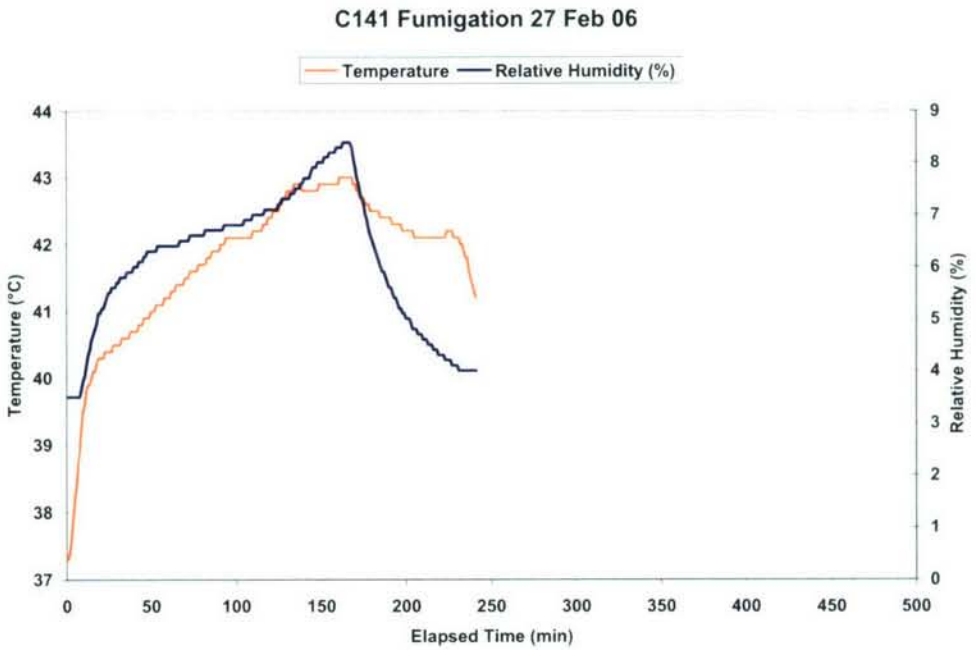


FIGURE B.1.8.2 WAS SENSOR 8, TEMP AND RH

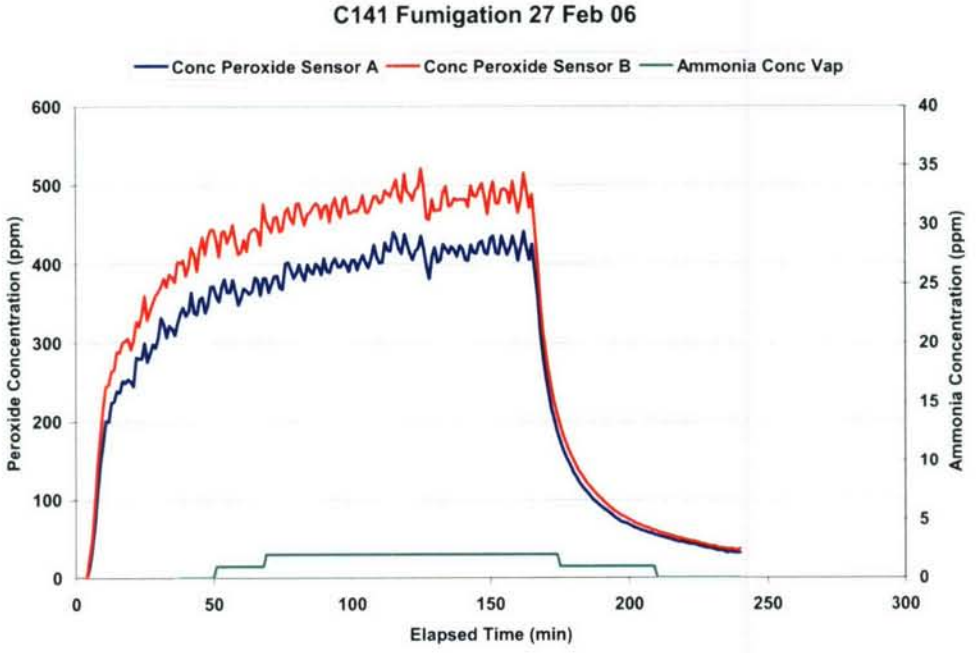


FIGURE B.1.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

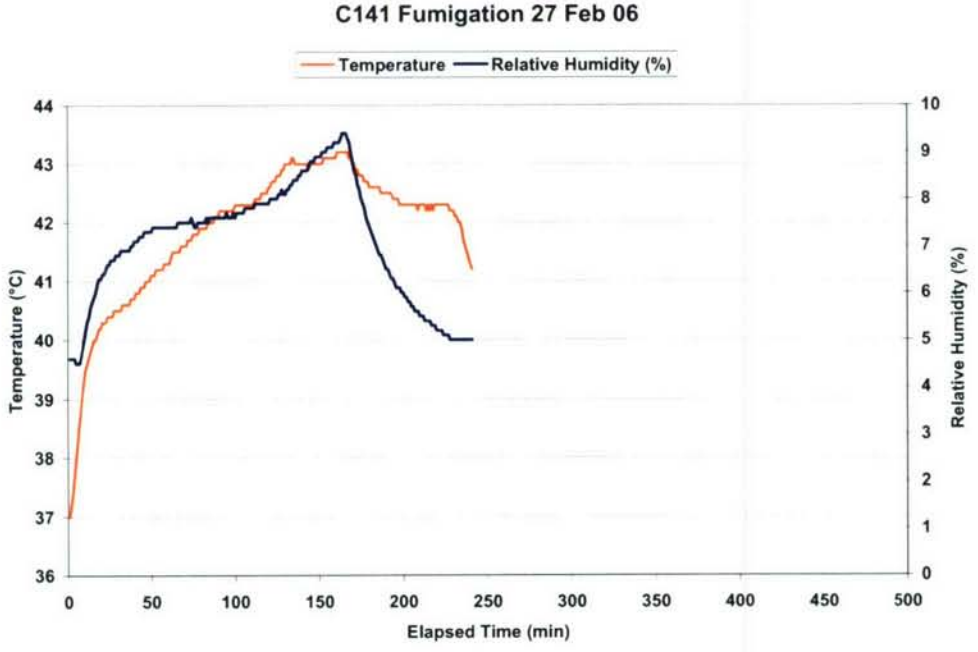


FIGURE B.1.9.2 WAS SENSOR 9, TEMP AND RH

B.2 Control Charts for 28 February 2006

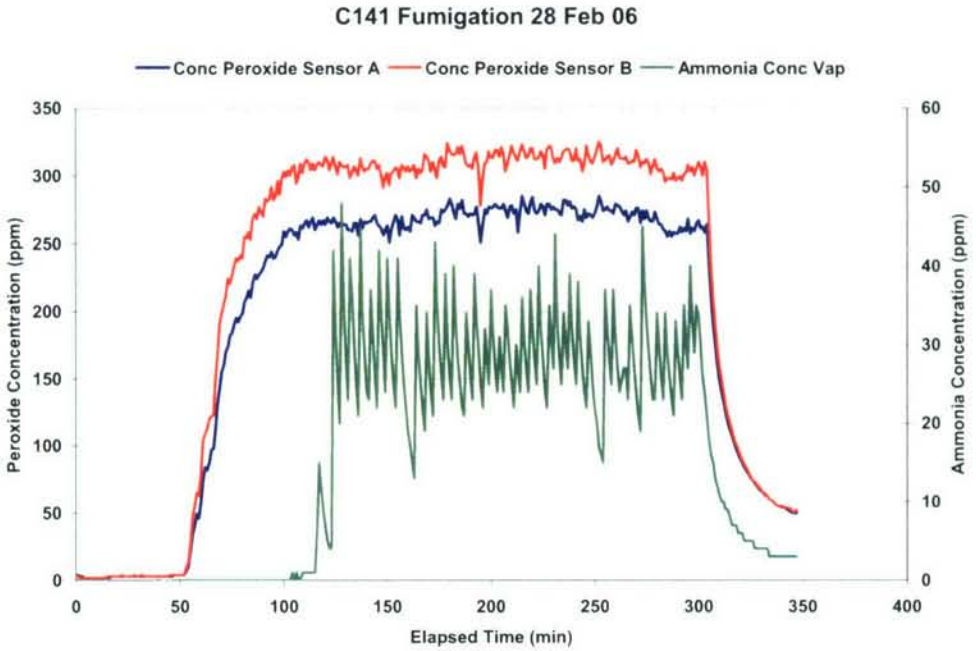


FIGURE B.2.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

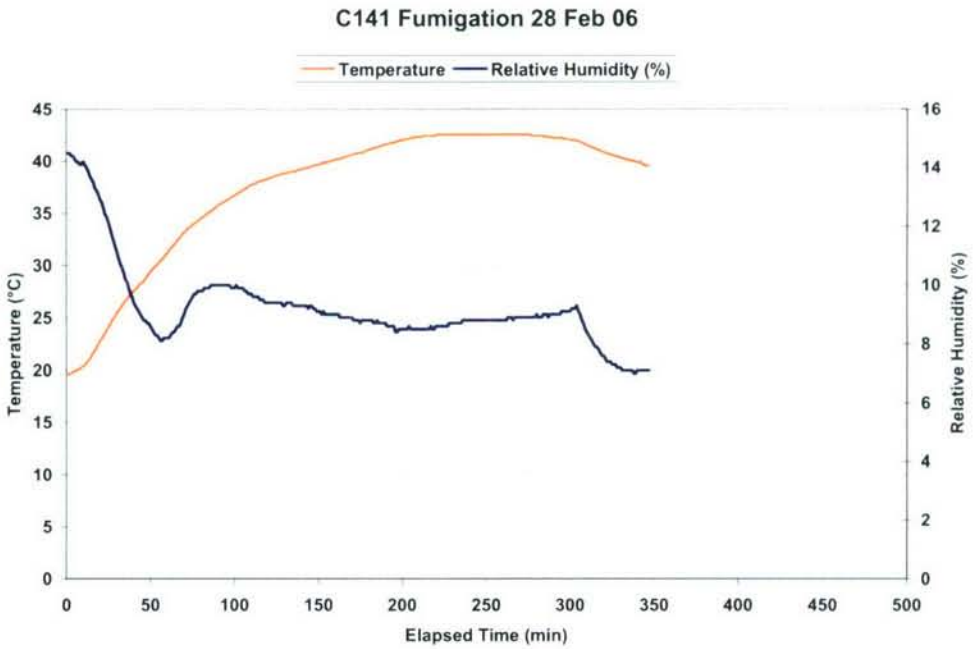


FIGURE B.2.1.2 WAS SENSOR 1, TEMP AND RH

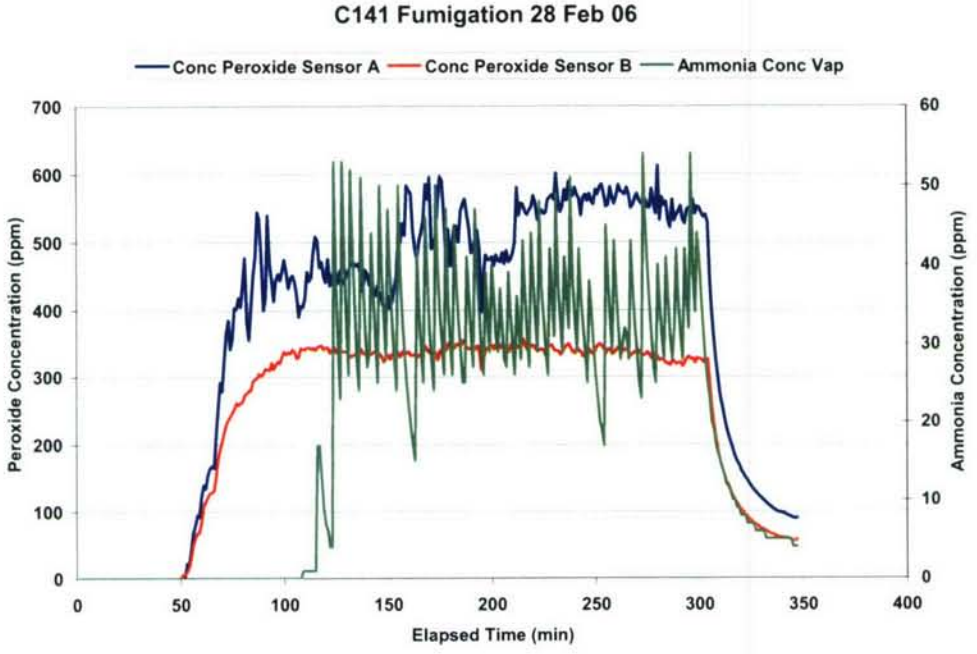


FIGURE B.2.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

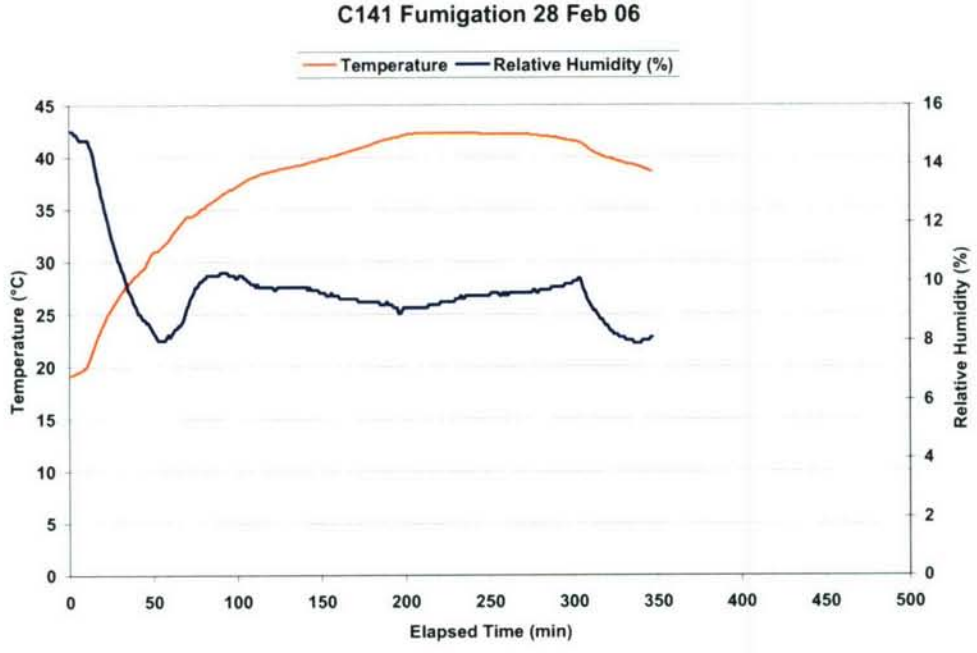


FIGURE B.2.2.2 WAS SENSOR 2, TEMP AND RH

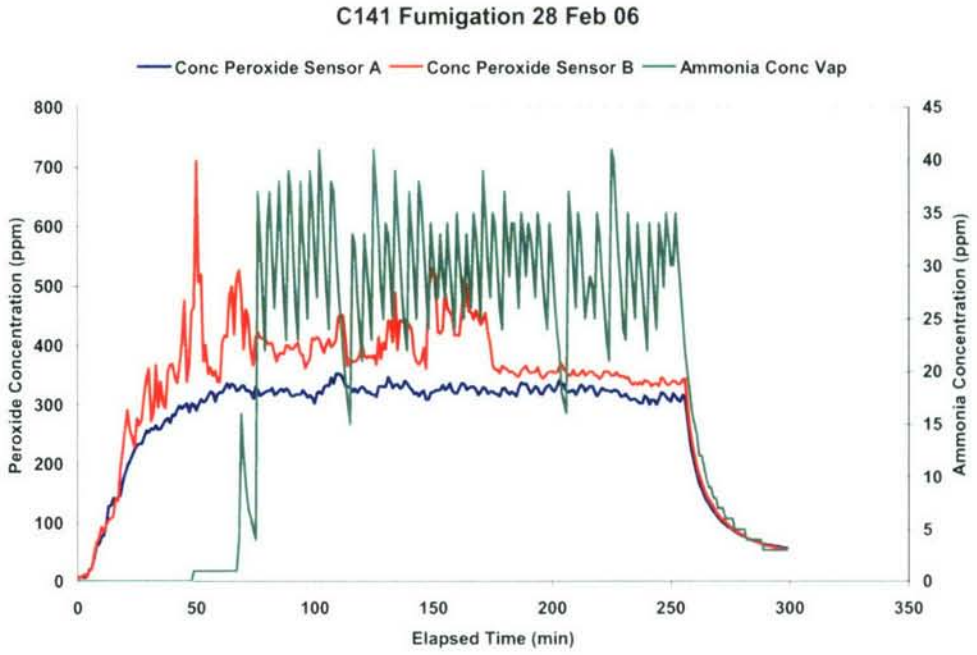


FIGURE B.2.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

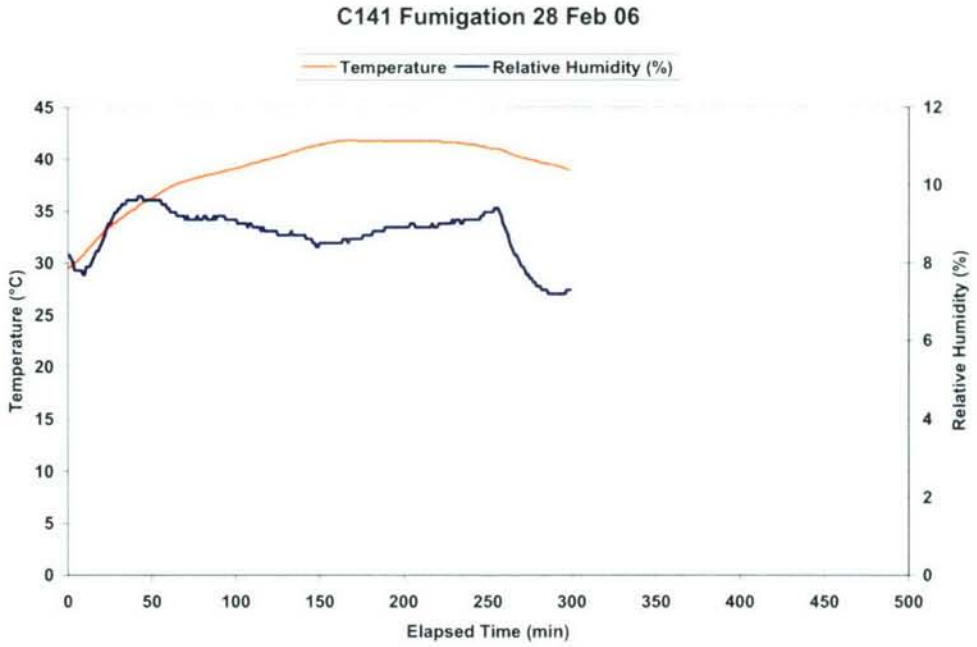


FIGURE B.2.3.2 WAS SENSOR 3, TEMP AND RH

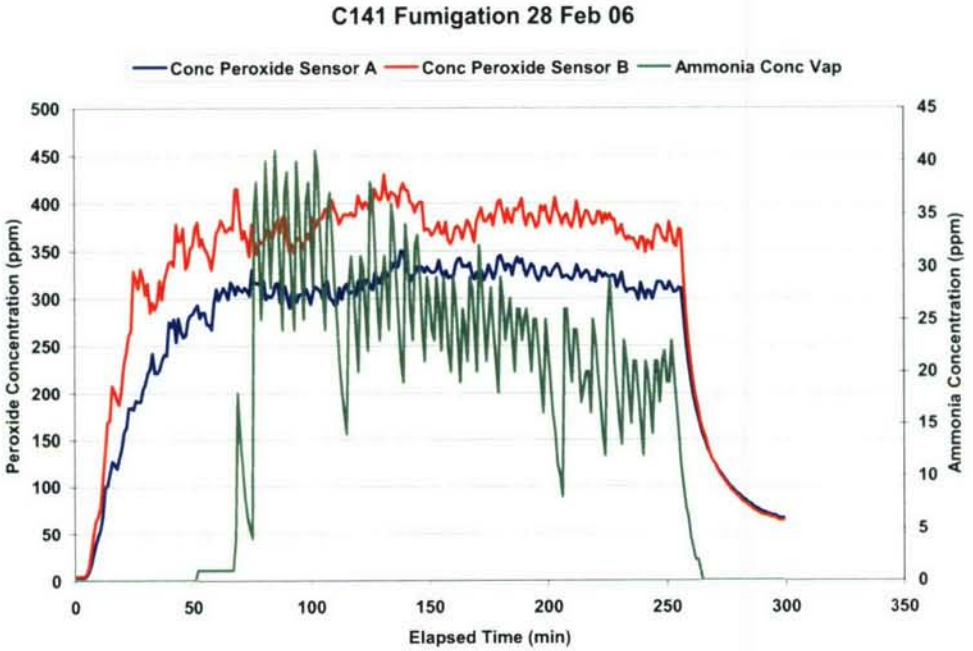


FIGURE B.2.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

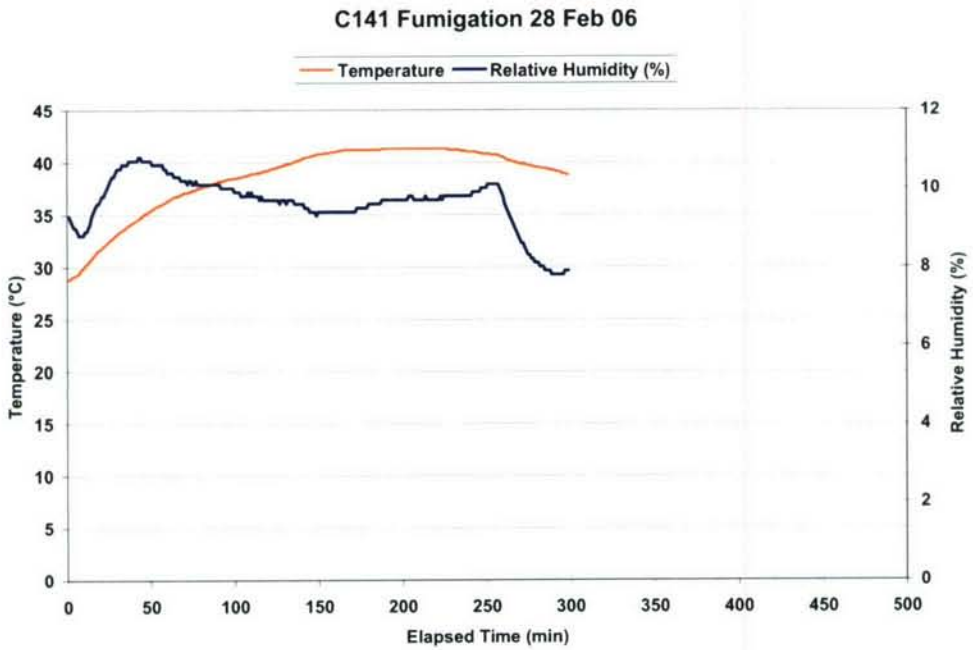


FIGURE B.2.4.2 WAS SENSOR 4, TEMP AND RH

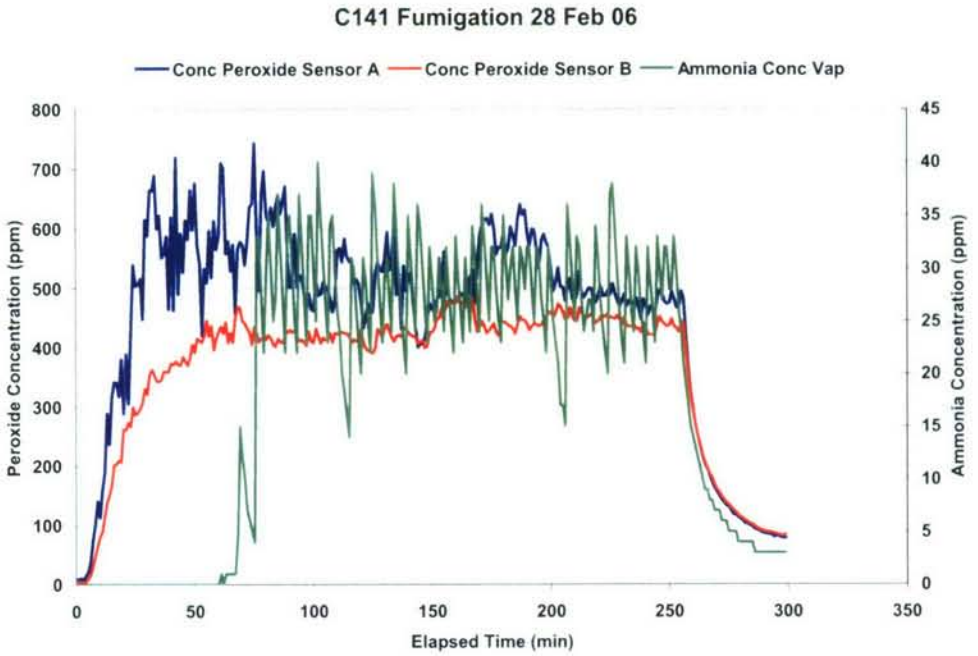


FIGURE B.2.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

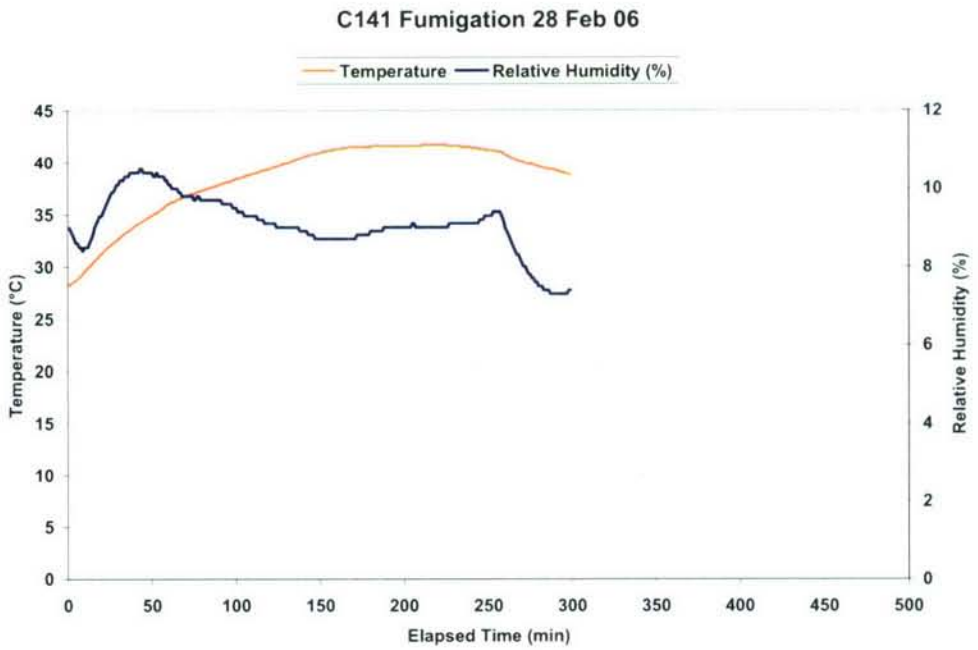


FIGURE B.2.5.2 WAS SENSOR 5, TEMP AND RH

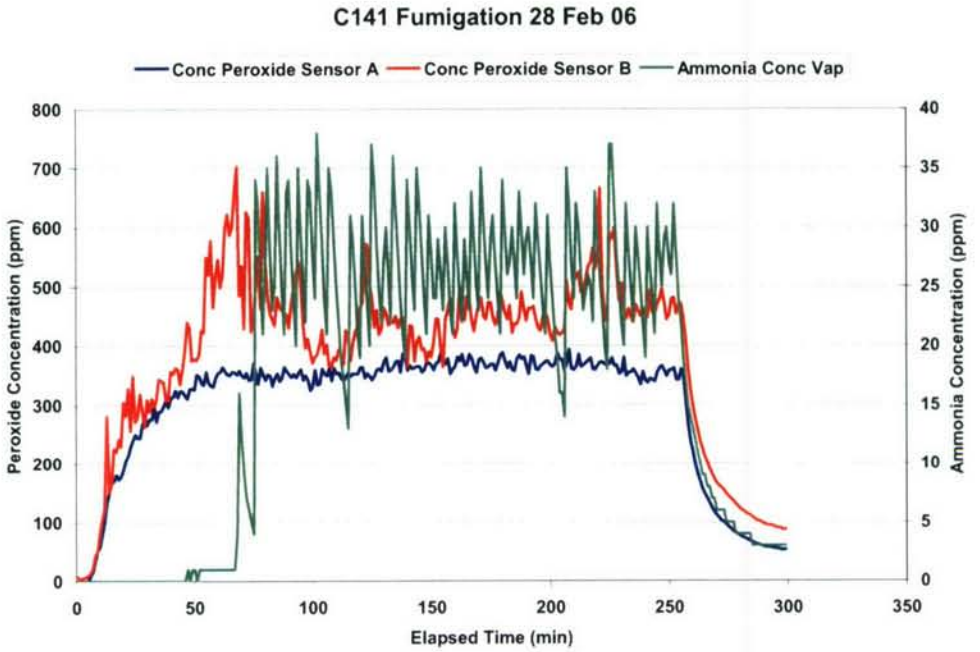


FIGURE B.2.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

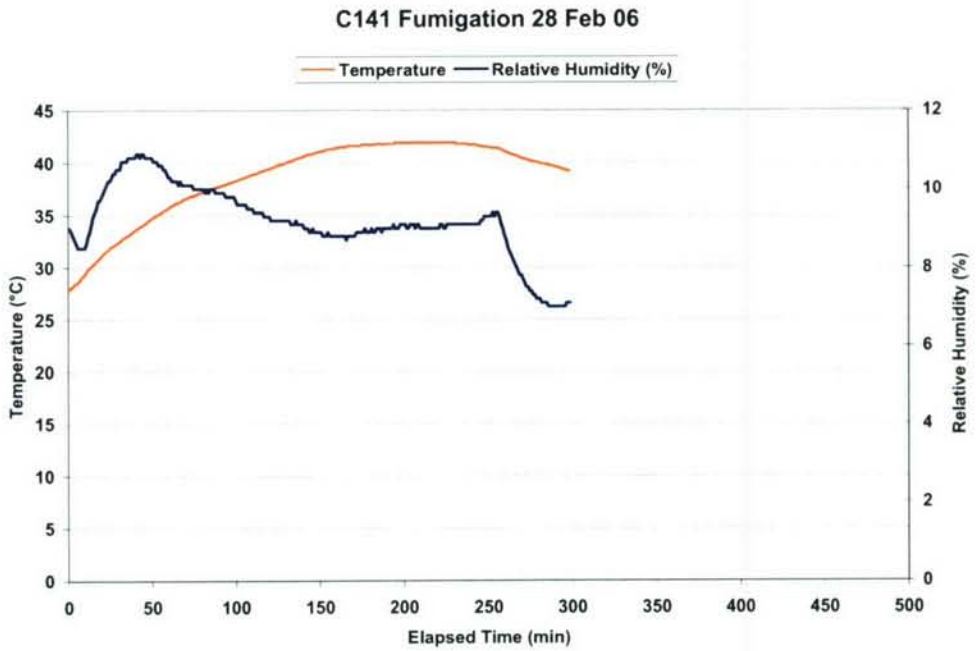


FIGURE B.2.6.2 WAS SENSOR 6, TEMP AND RH

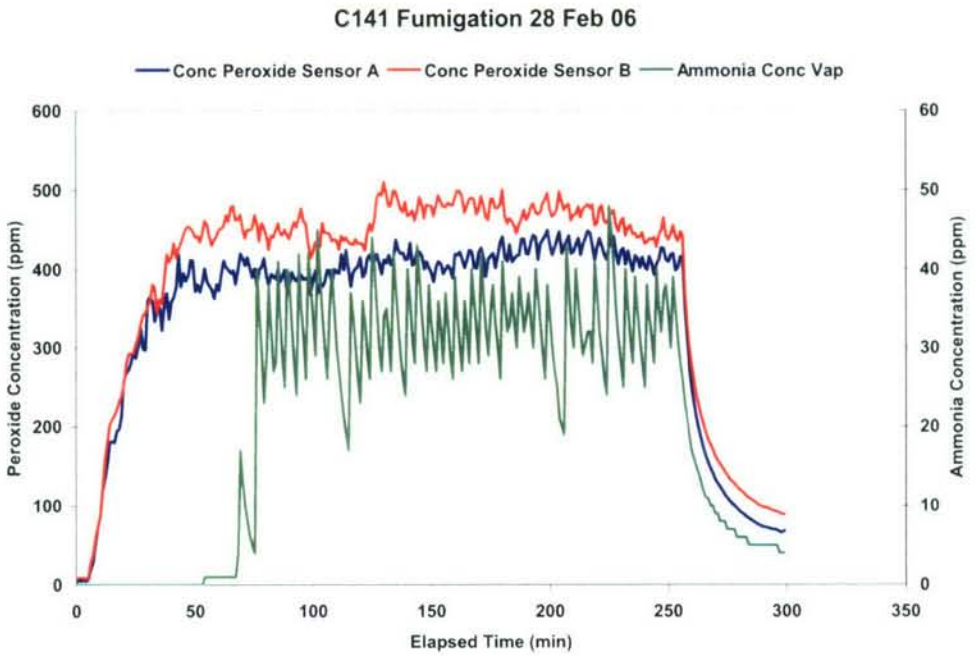


FIGURE B.2.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

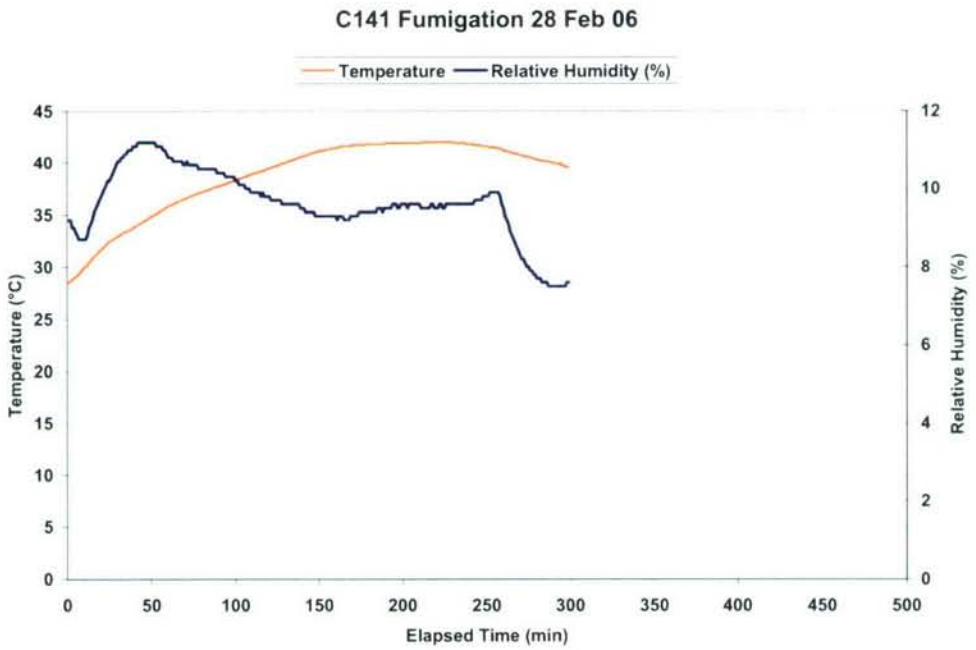


FIGURE B.2.7.2 WAS SENSOR 7, TEMP AND RH

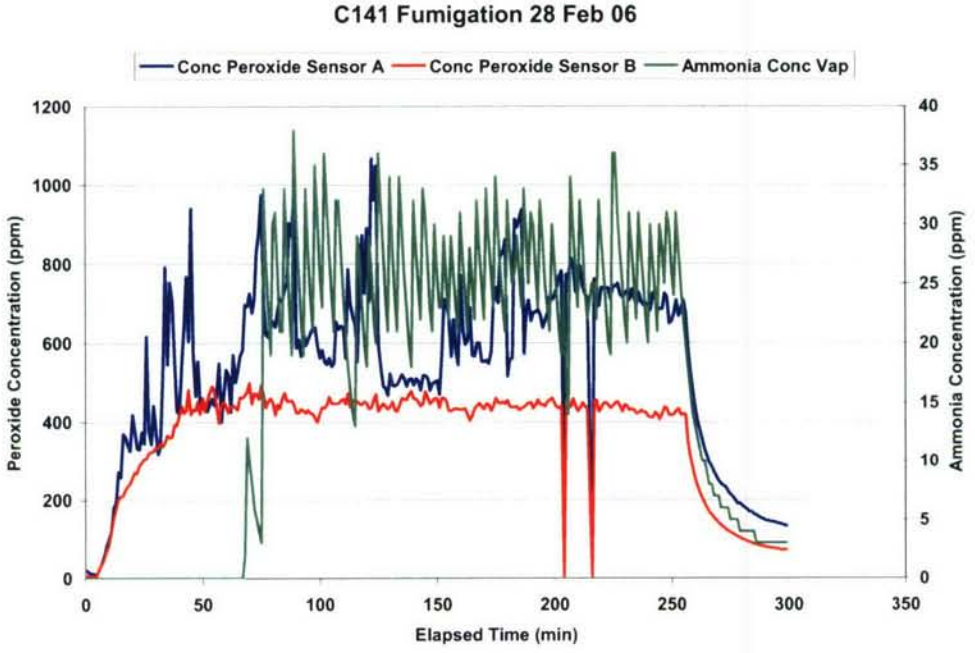


FIGURE B.2.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

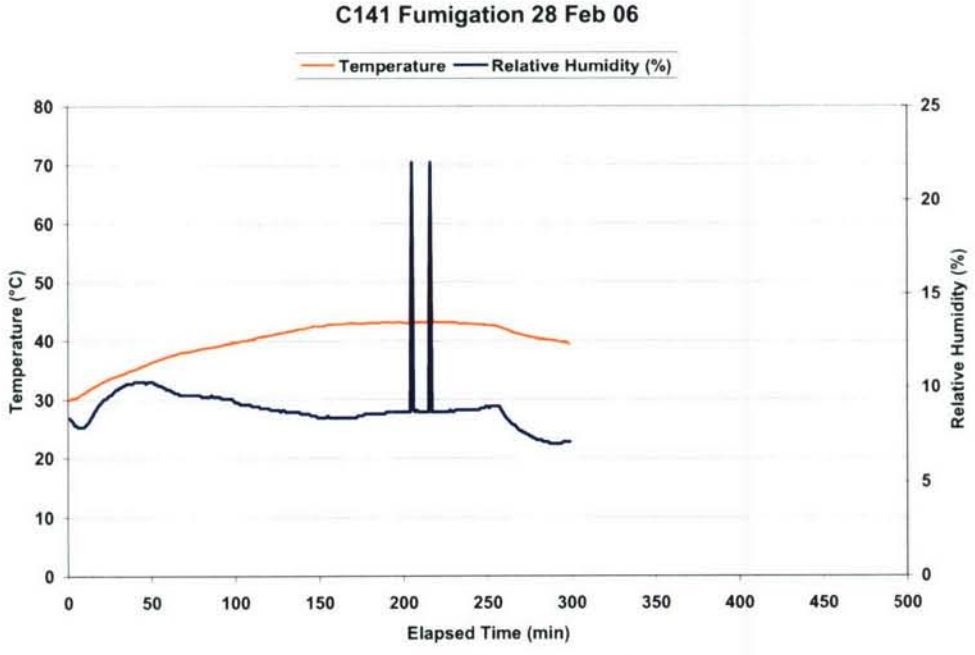


FIGURE B.2.8.2 WAS SENSOR 8, TEMP AND RH

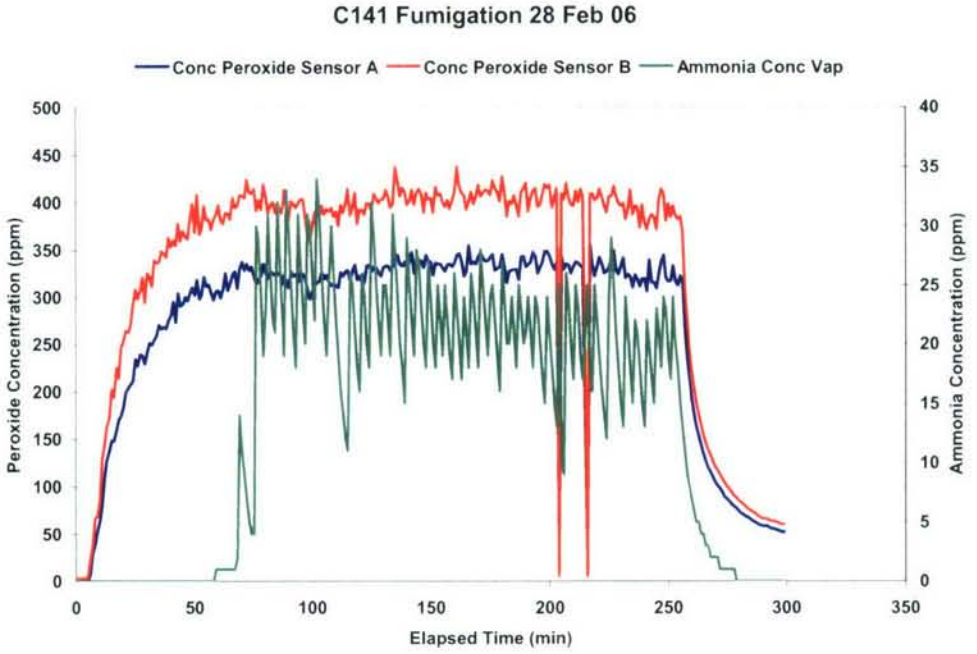


FIGURE B.2.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

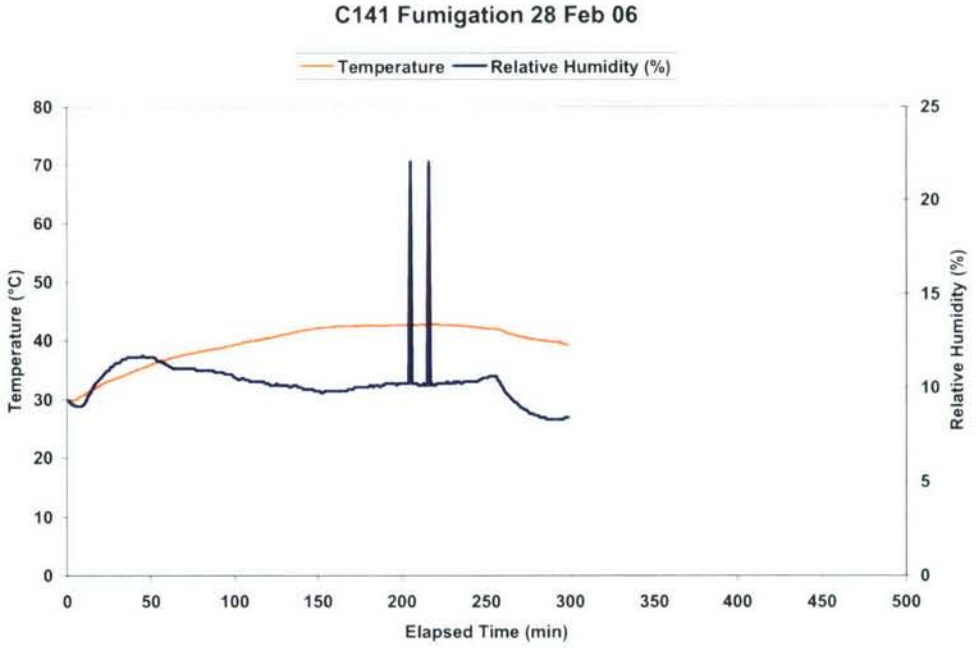


FIGURE B.2.9.2 WAS SENSOR 9, TEMP AND RH

B.3 Control Charts for 2 March 2006

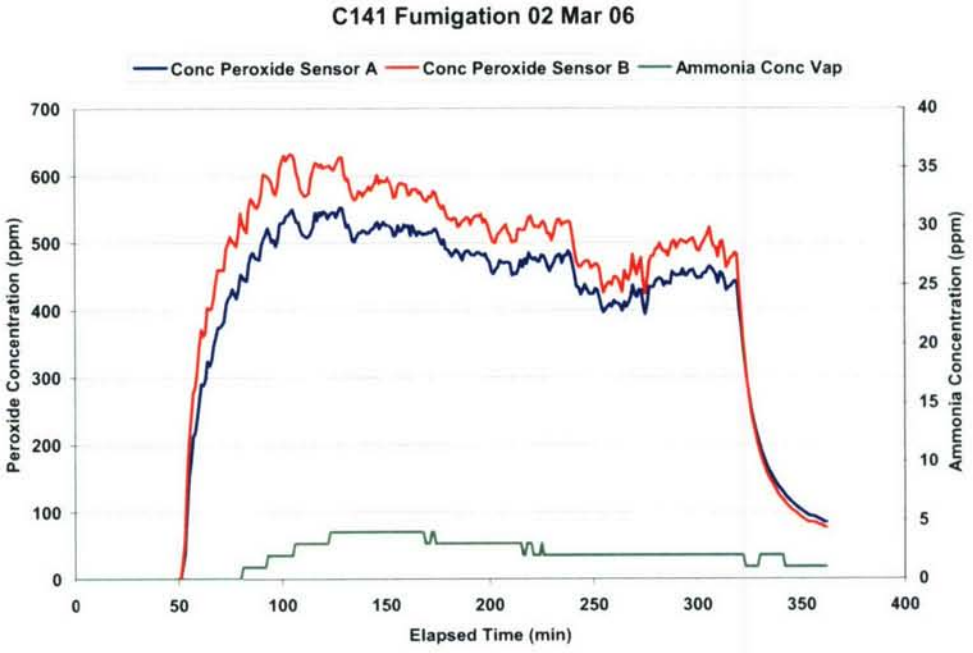


FIGURE B.3.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

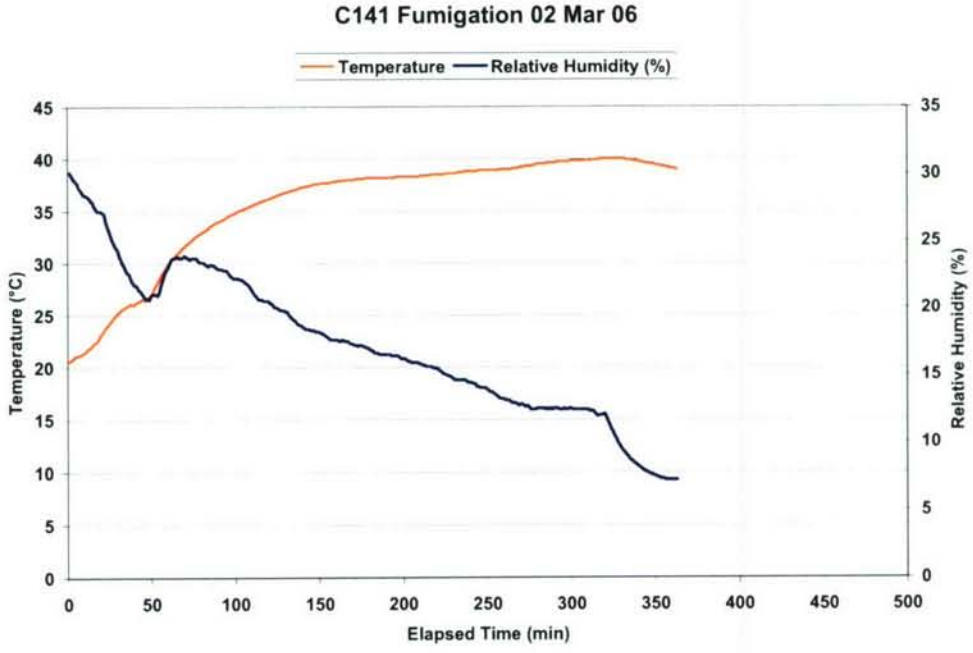


FIGURE B.3.1.2 WAS SENSOR 1, TEMP AND RH

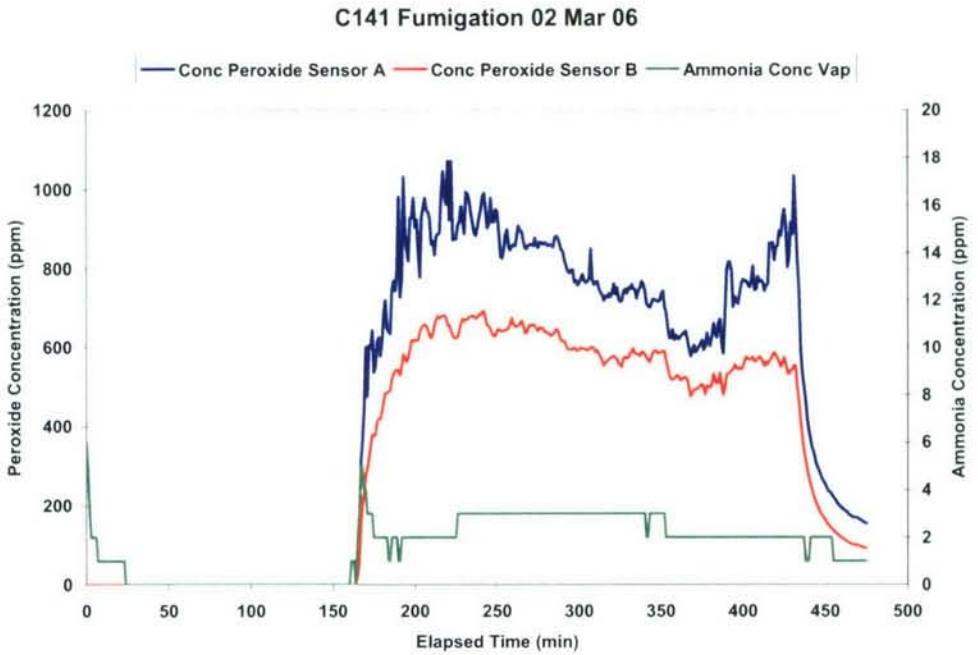


FIGURE B.3.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

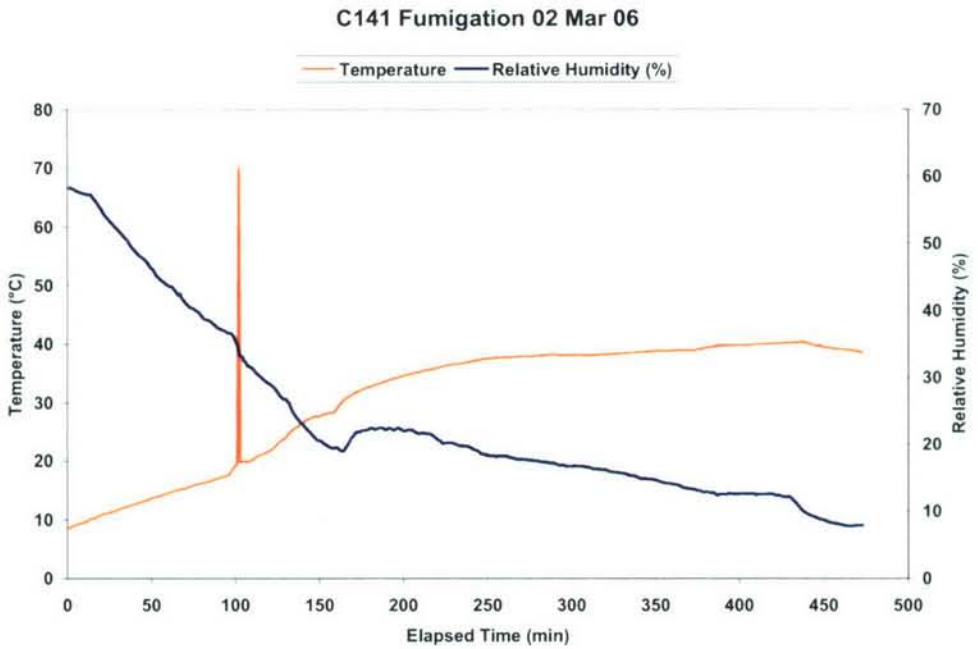


FIGURE B.3.2.2 WAS SENSOR 2, TEMP AND RH

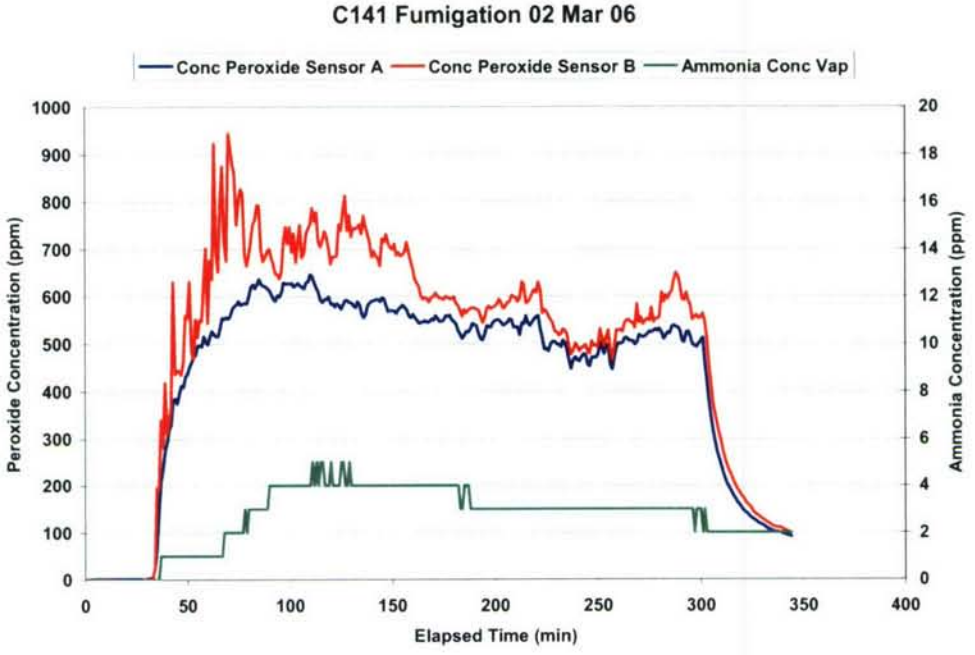


FIGURE B.3.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

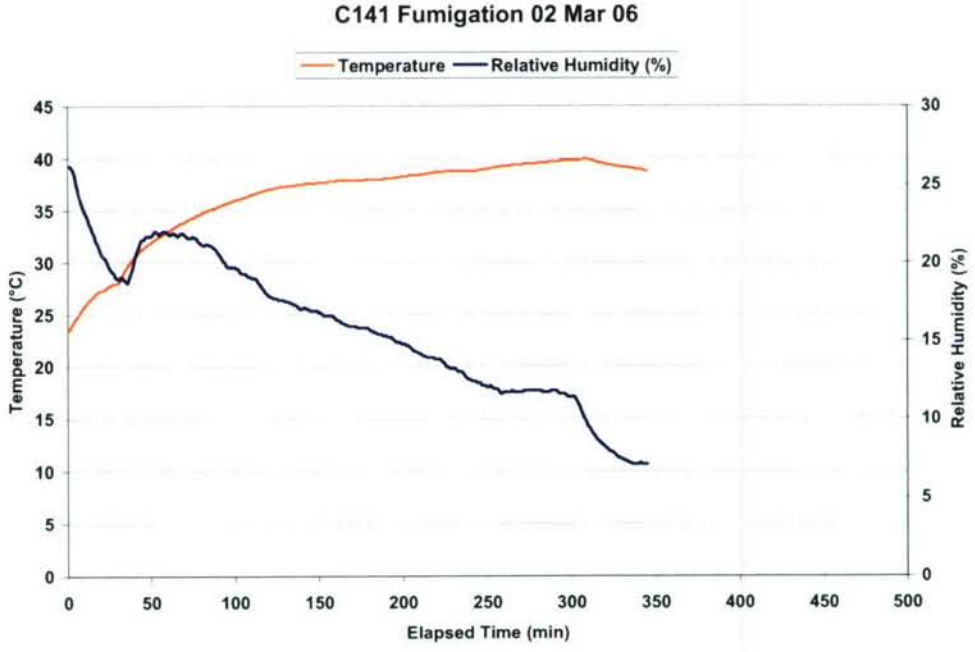


FIGURE B.3.3.2 WAS SENSOR 3, TEMP AND RH

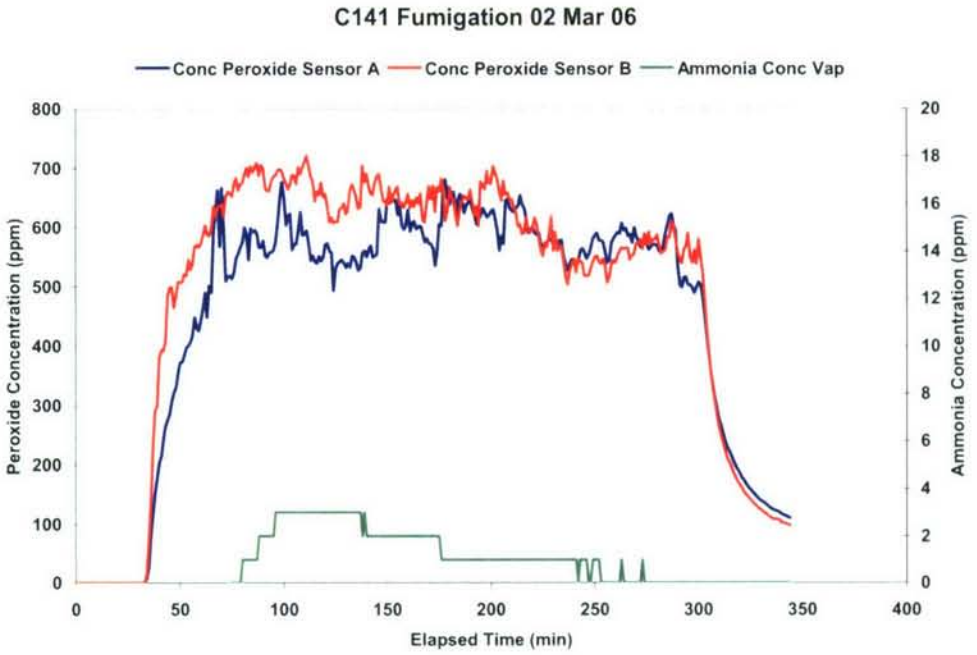


FIGURE B.3.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

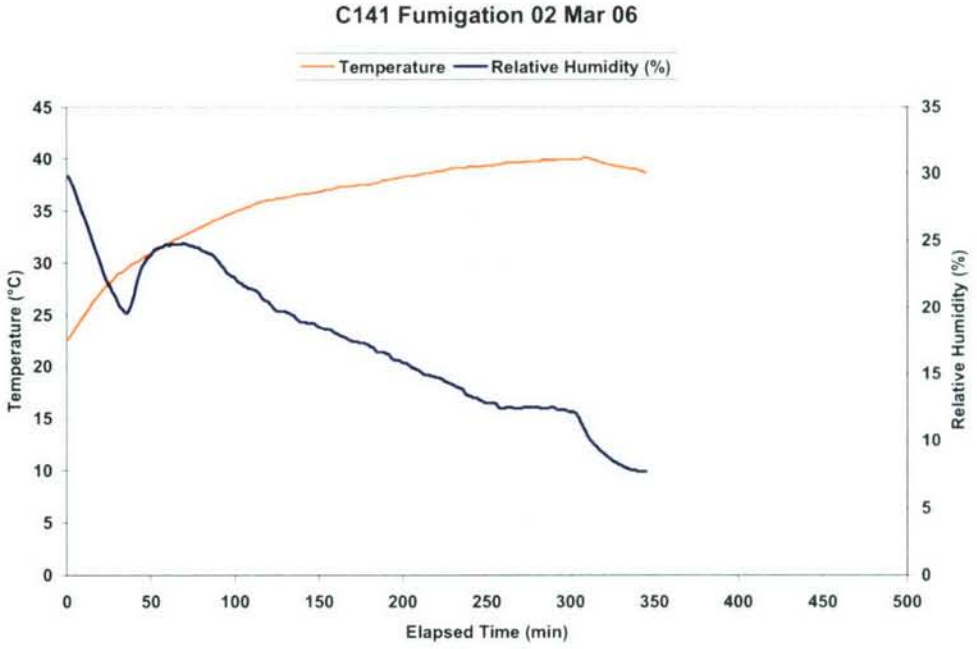


FIGURE B.3.4.2 WAS SENSOR 4, TEMP AND RH

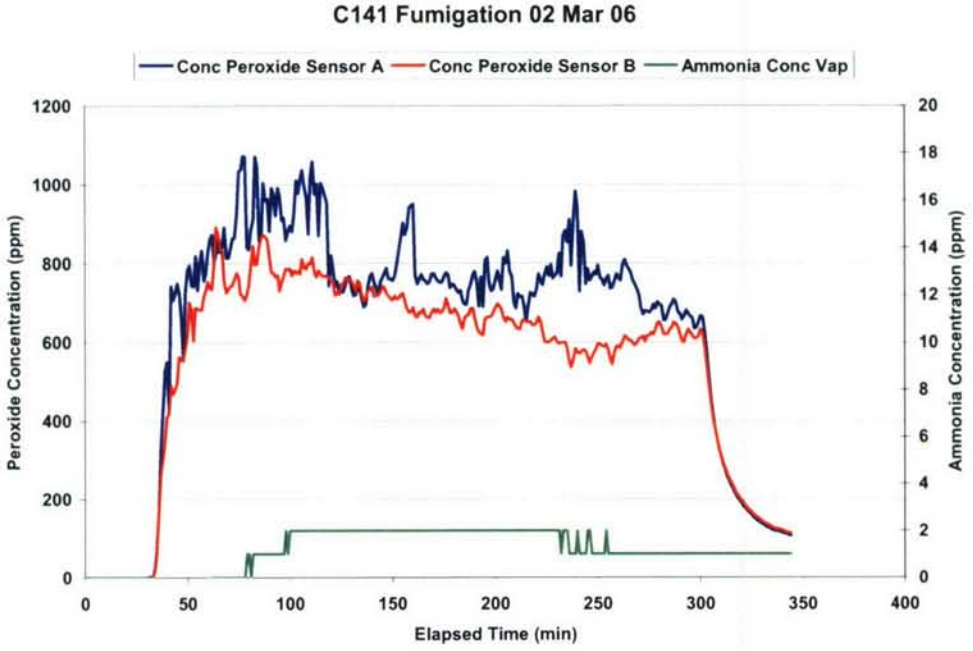


FIGURE B.3.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

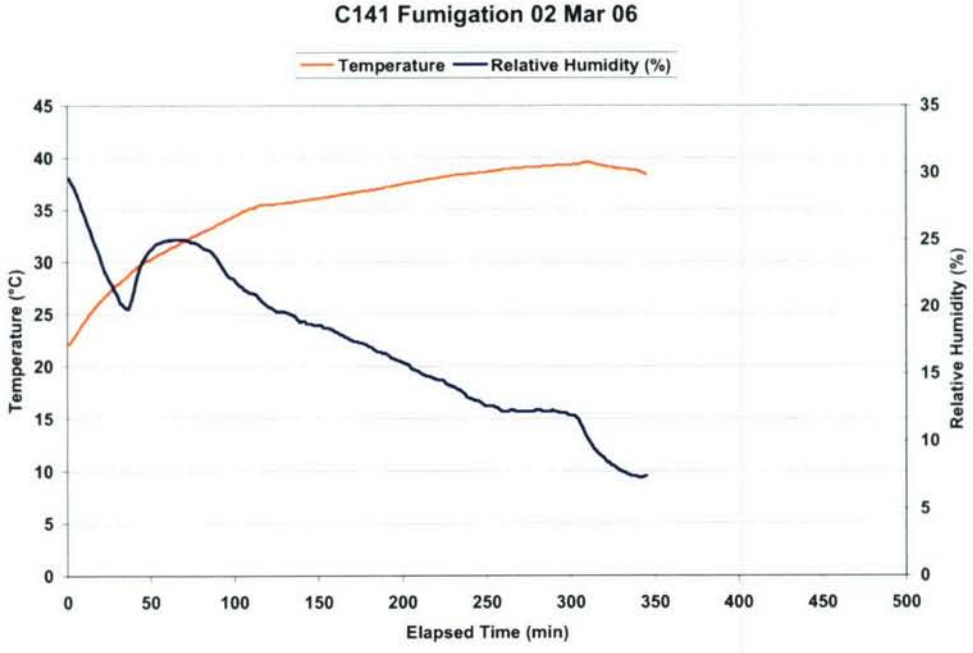


FIGURE B.3.5.2 WAS SENSOR 5, TEMP AND RH

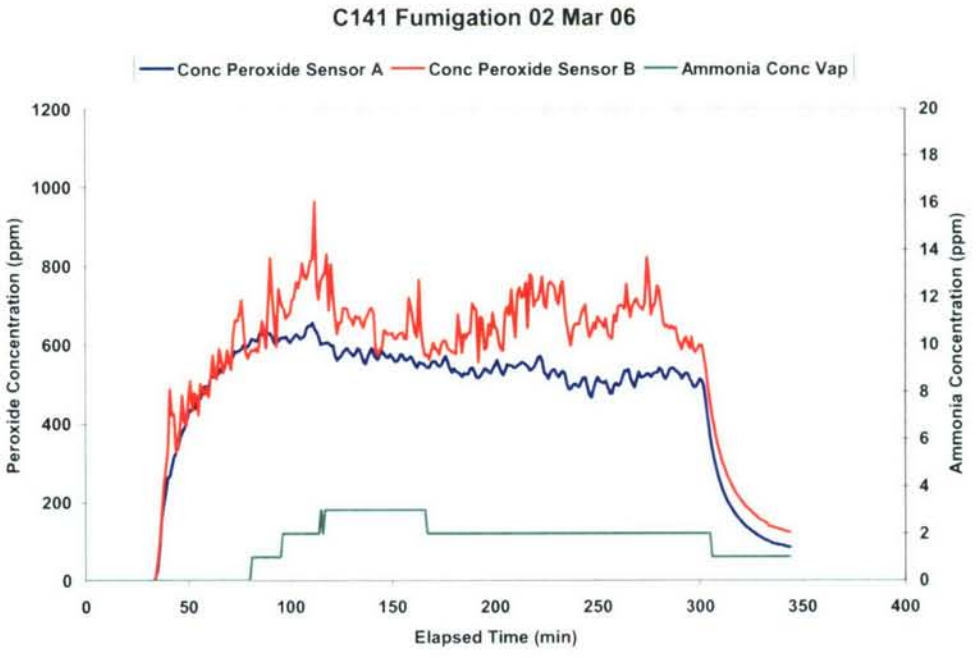


FIGURE B.3.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

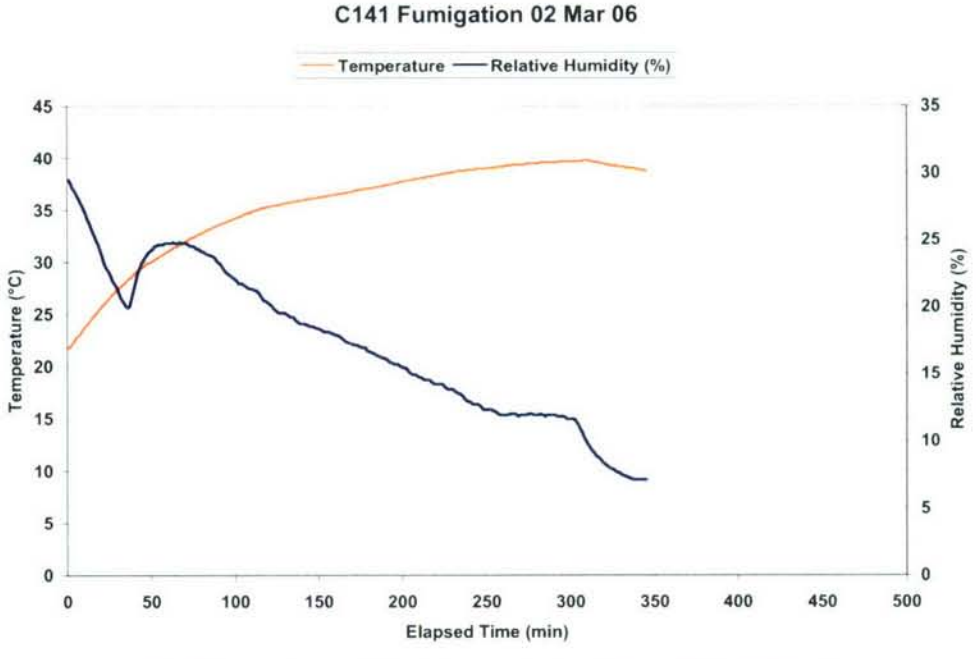


FIGURE B.3.6.2 WAS SENSOR 6, TEMP AND RH

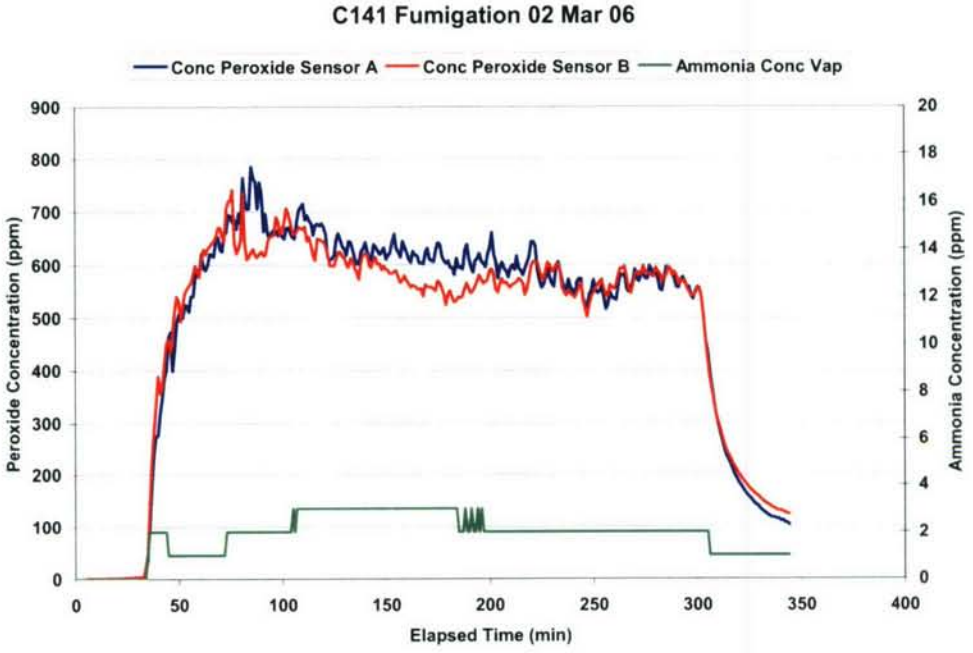


FIGURE B.3.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

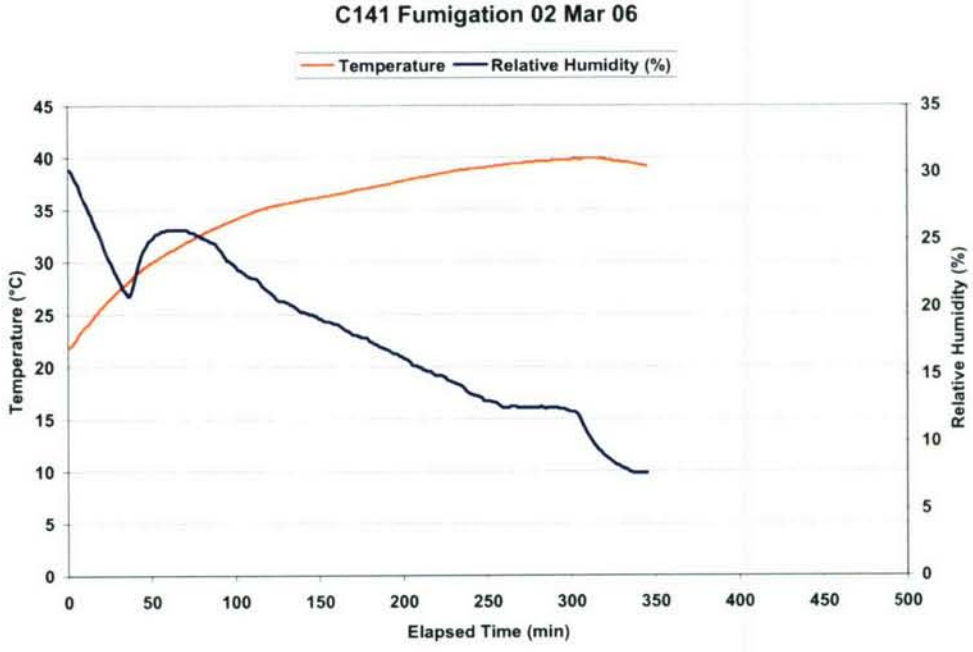


FIGURE B.3.7.2 WAS SENSOR 7, TEMP AND RH

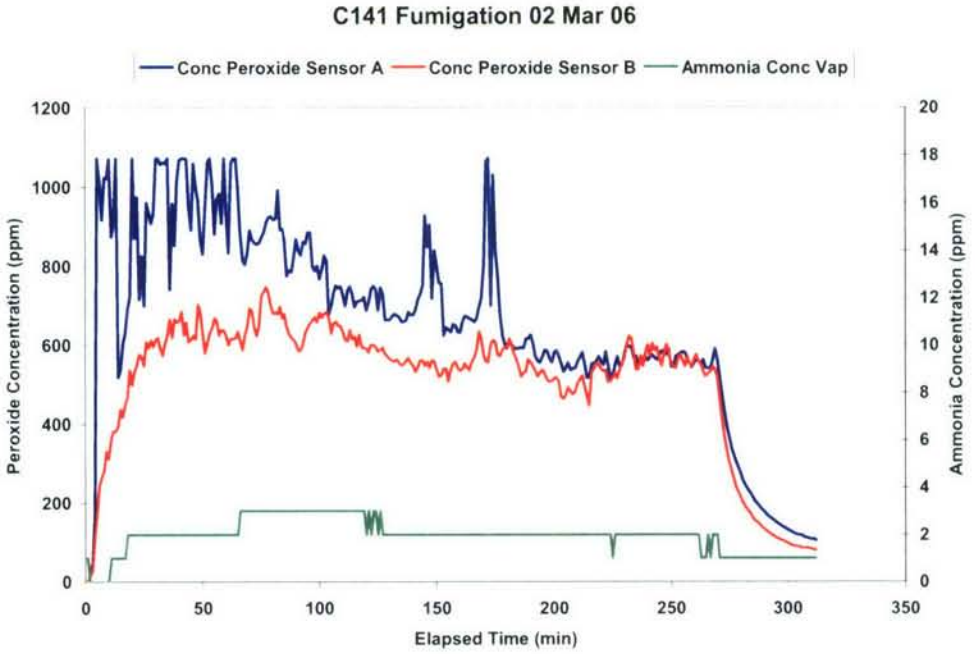


FIGURE B.3.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

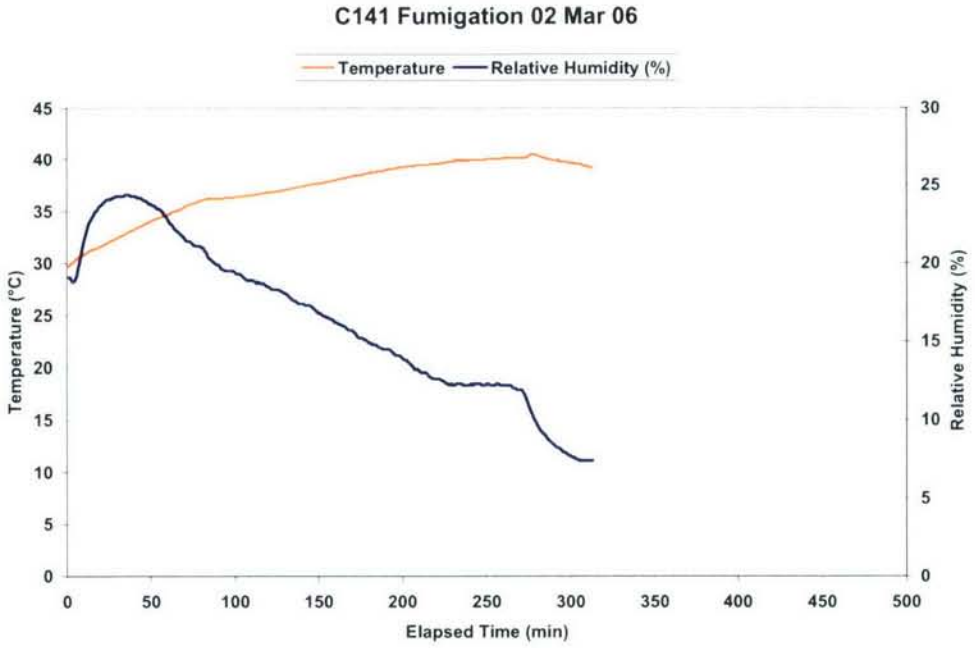


FIGURE B.3.8.2 WAS SENSOR 8, TEMP AND RH

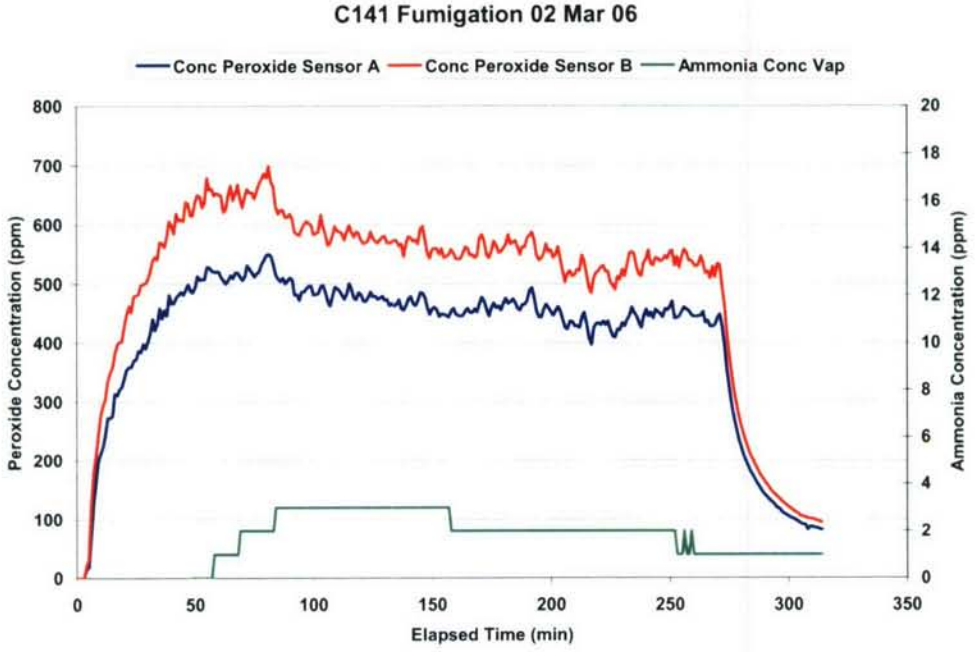


FIGURE B.3.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

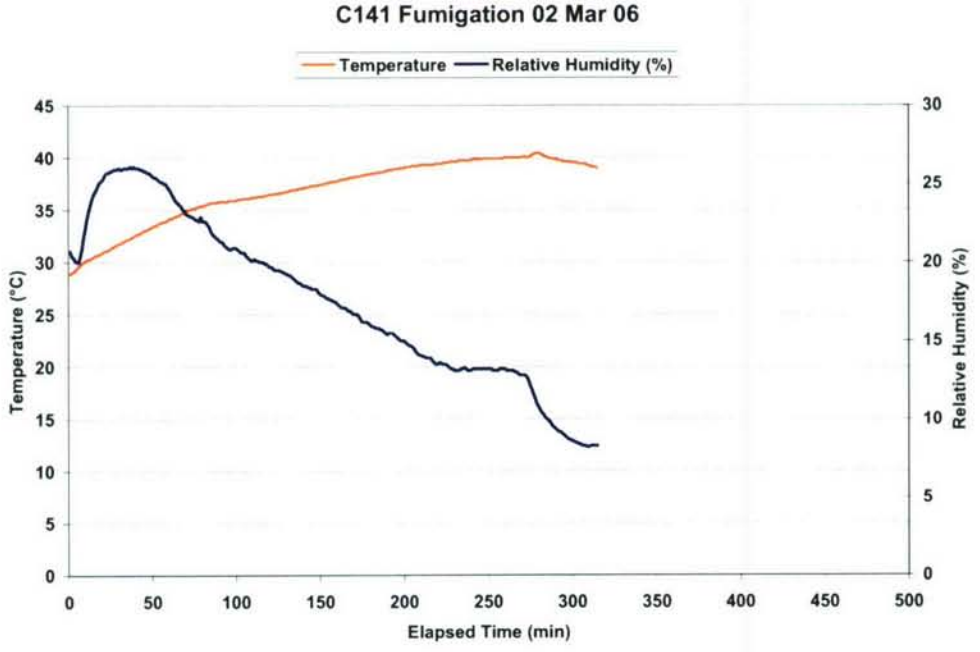


FIGURE B.3.9.2 WAS SENSOR 9, TEMP AND RH

B.4 Control Charts for 3 March 2006

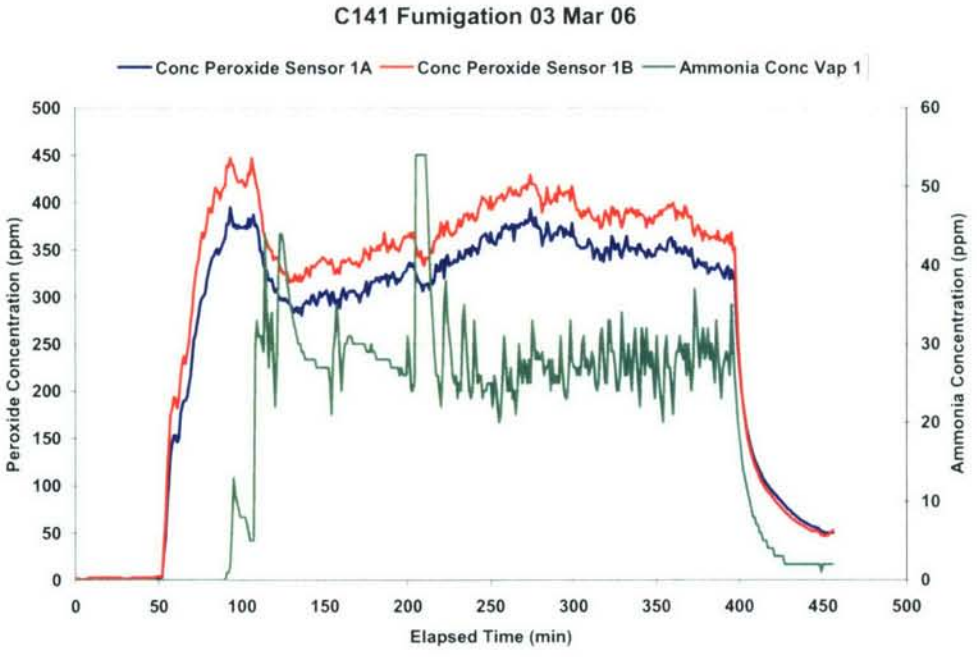


FIGURE B.4.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

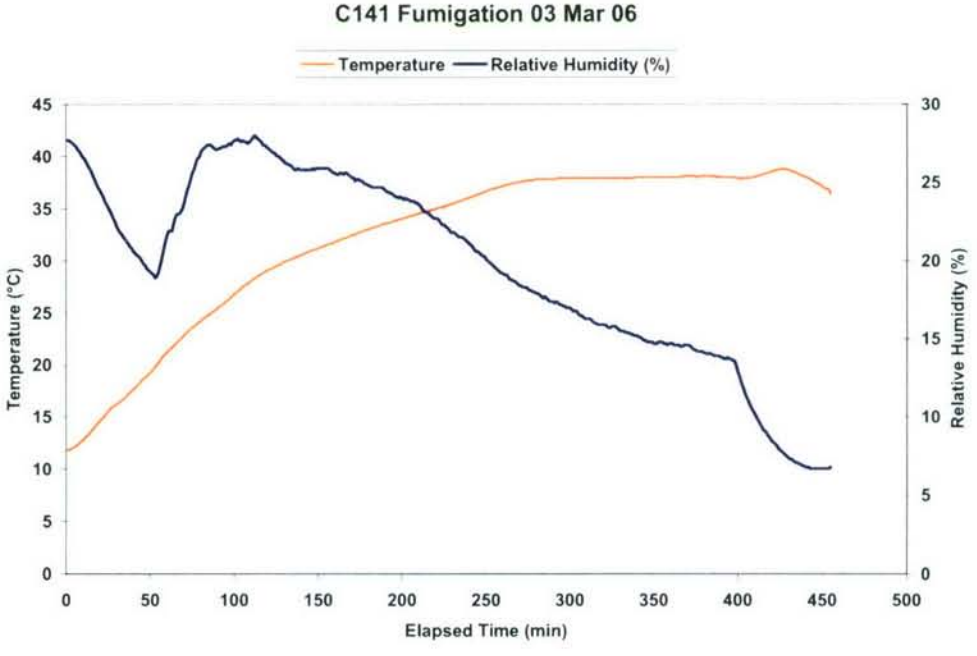


FIGURE B.4.1.2 WAS SENSOR 1, TEMP AND RH

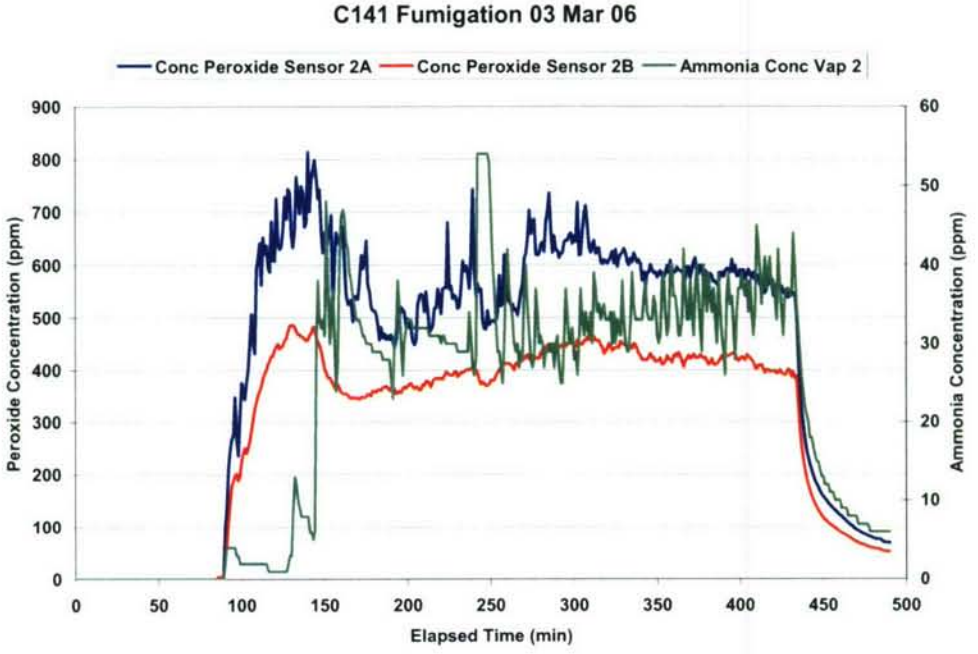


FIGURE B.4.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

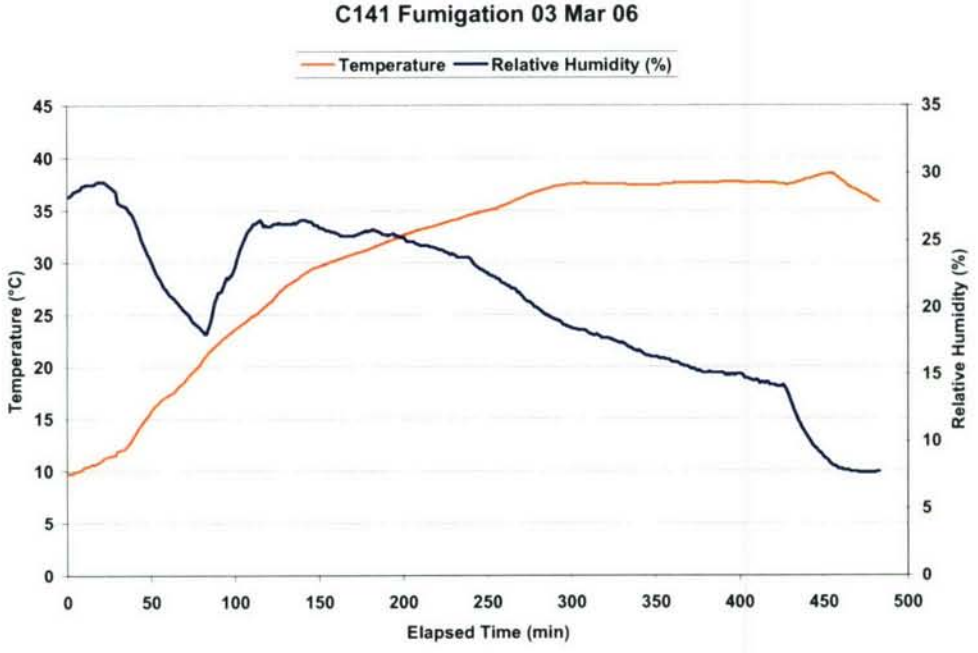


FIGURE B.4.2.2 WAS SENSOR 2, TEMP AND RH

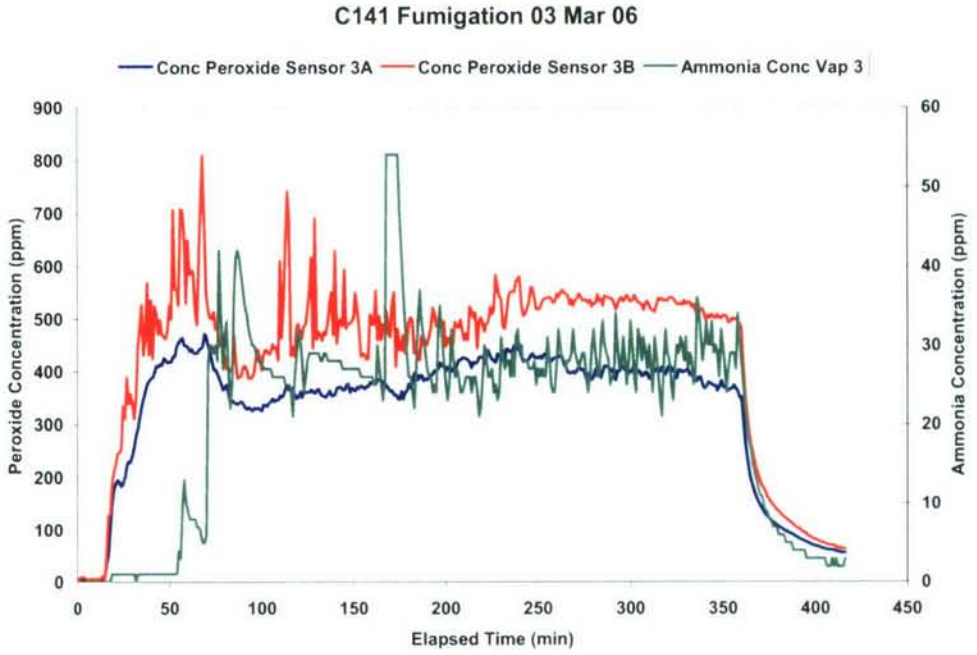


FIGURE B.4.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

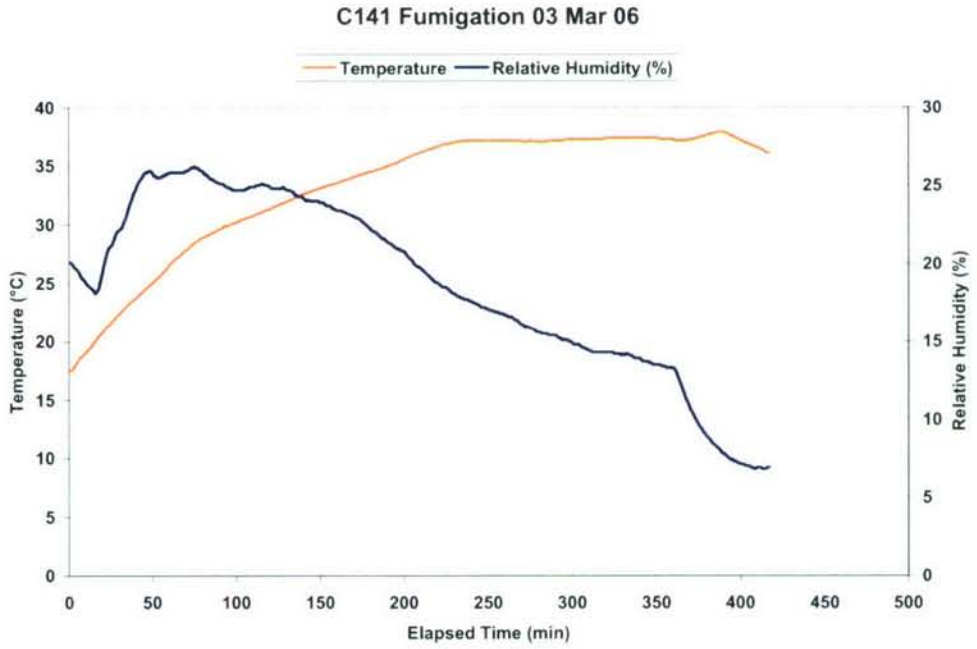


FIGURE B.4.3.2 WAS SENSOR 3, TEMP AND RH

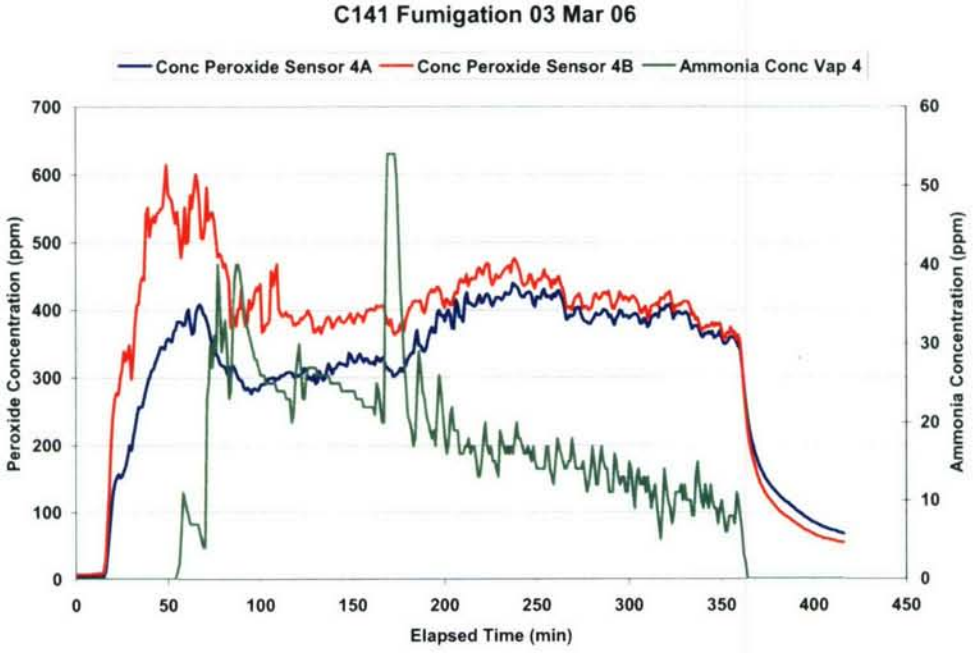


FIGURE B.4.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

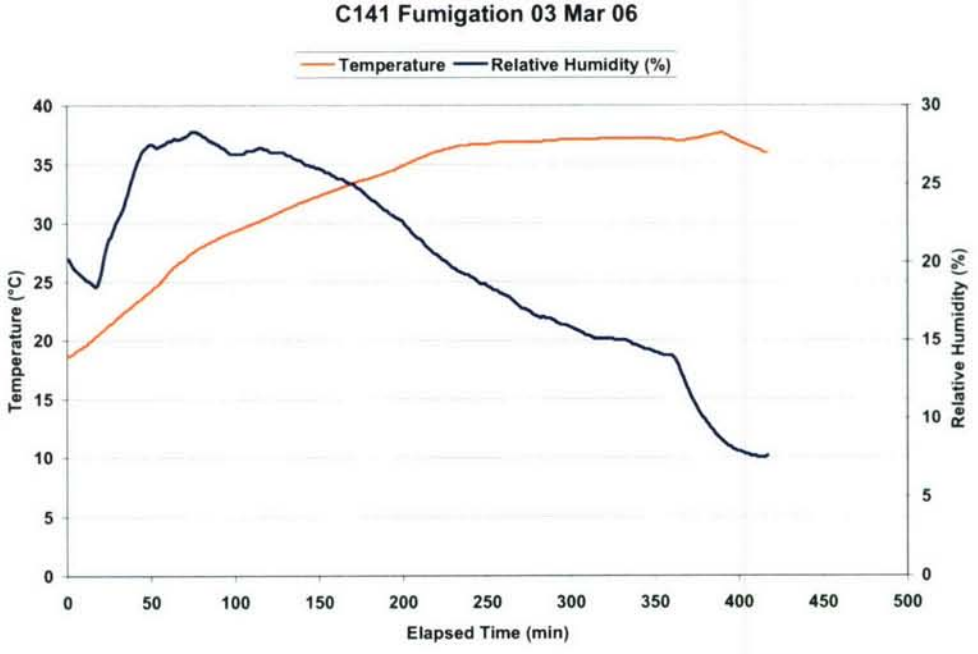


FIGURE B.4.4.2 WAS SENSOR 4, TEMP AND RH

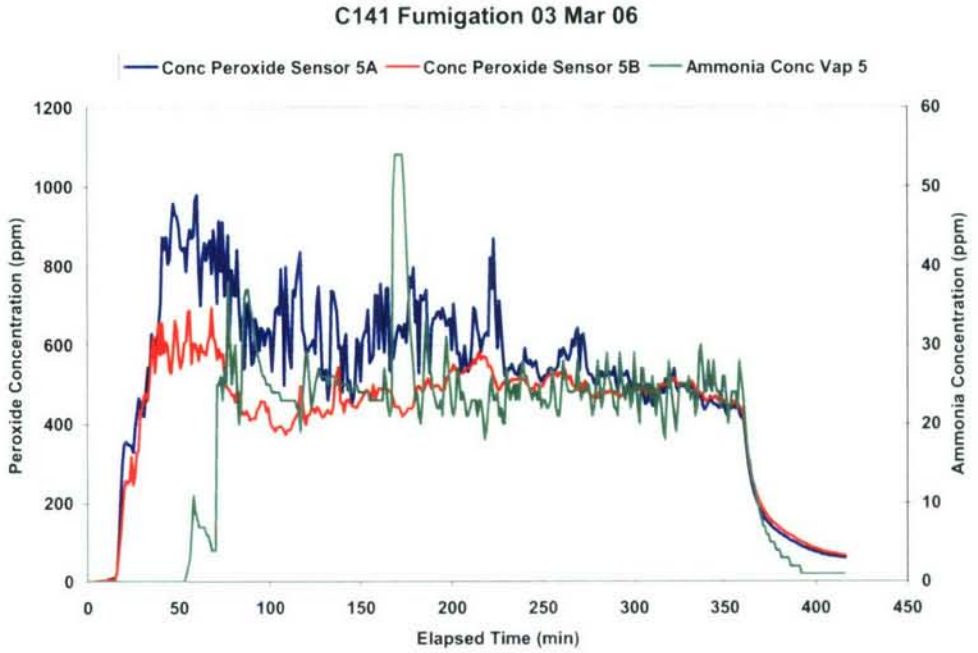


FIGURE B.4.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

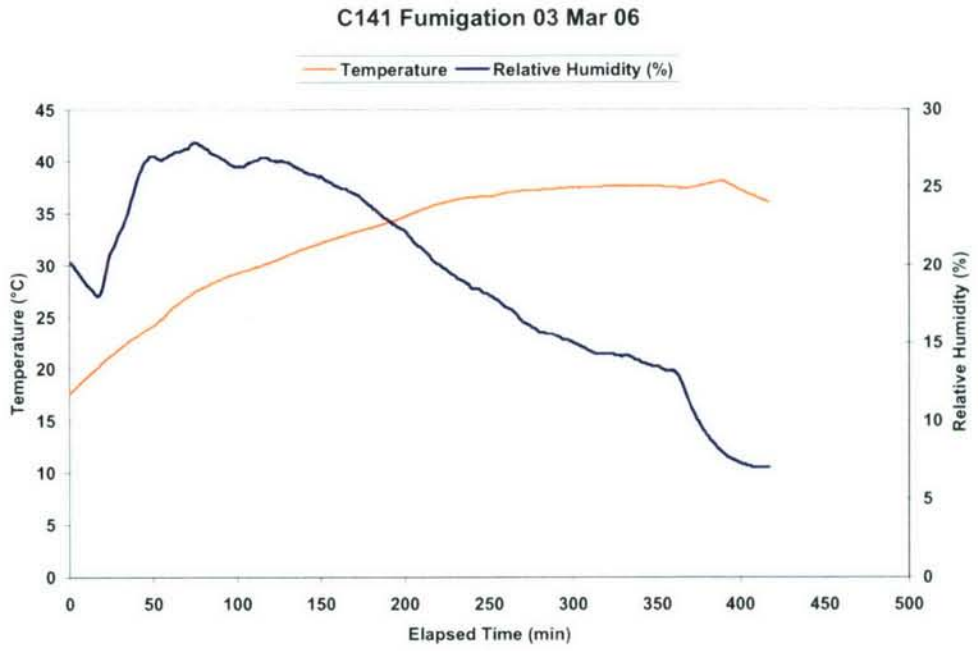


FIGURE B.4.5.2 WAS SENSOR 5, TEMP AND RH

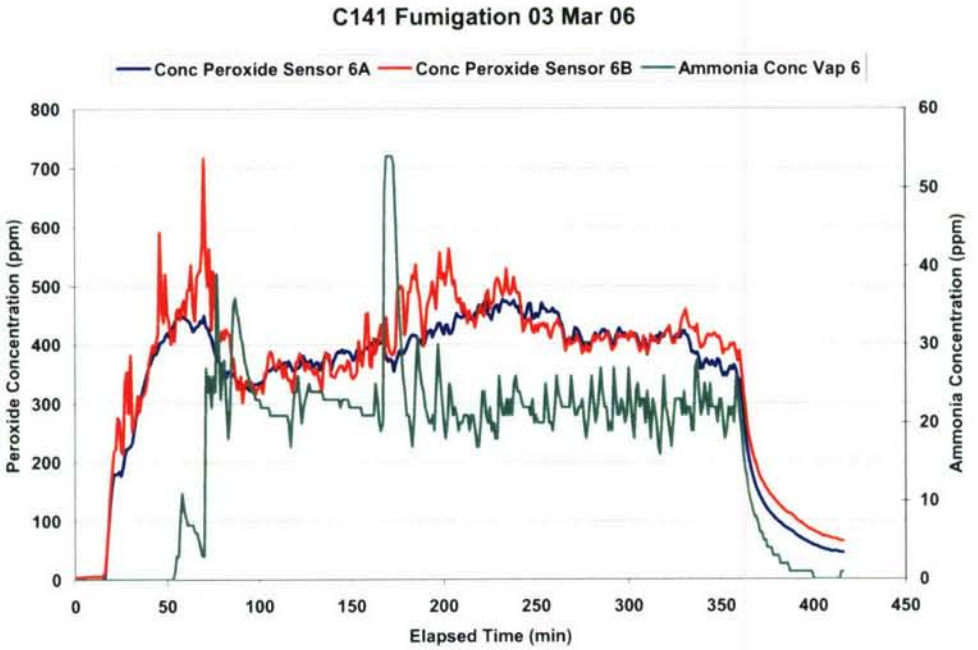


FIGURE B.4.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

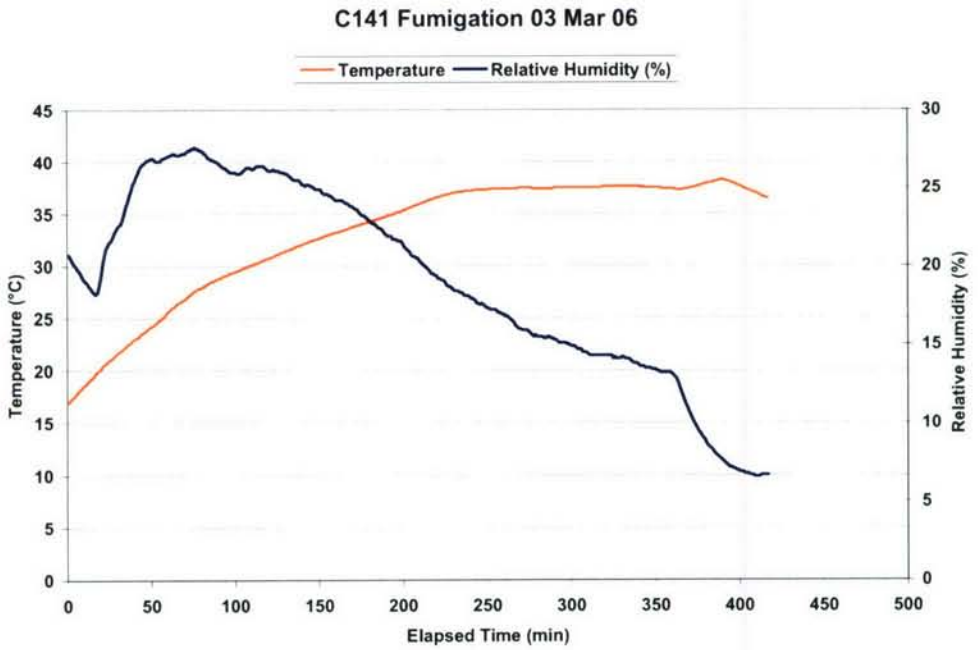


FIGURE B.4.6.2 WAS SENSOR 6, TEMP AND RH

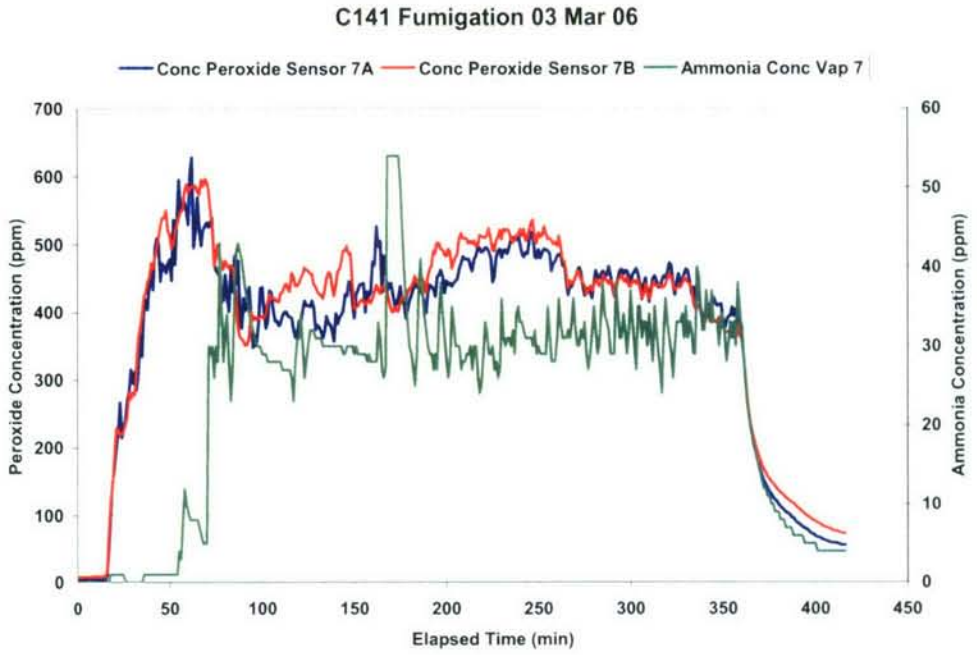


FIGURE B.4.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

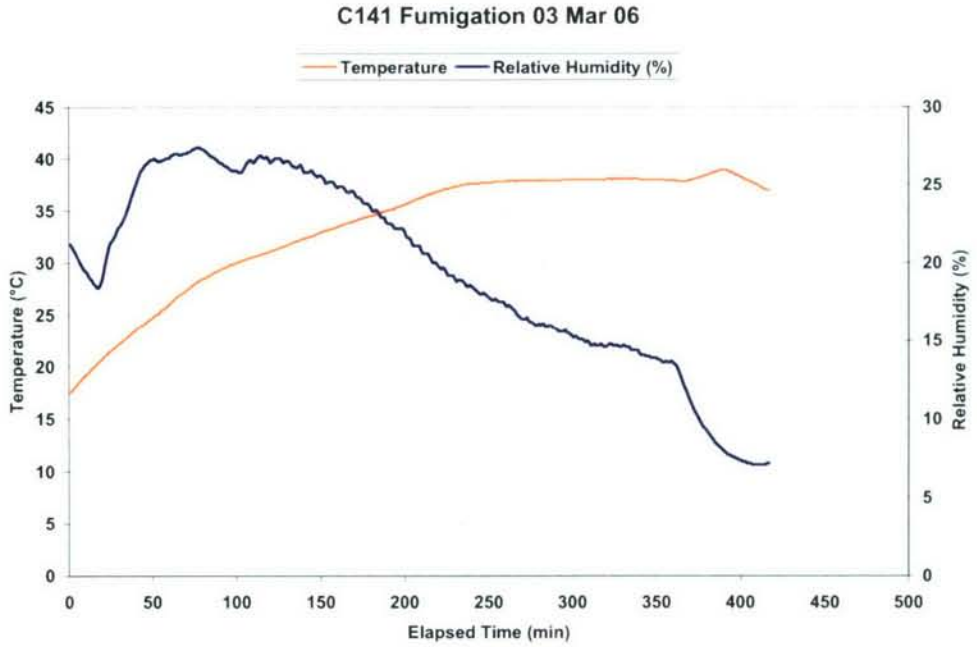


FIGURE B.4.7.2 WAS SENSOR 7, TEMP AND RH

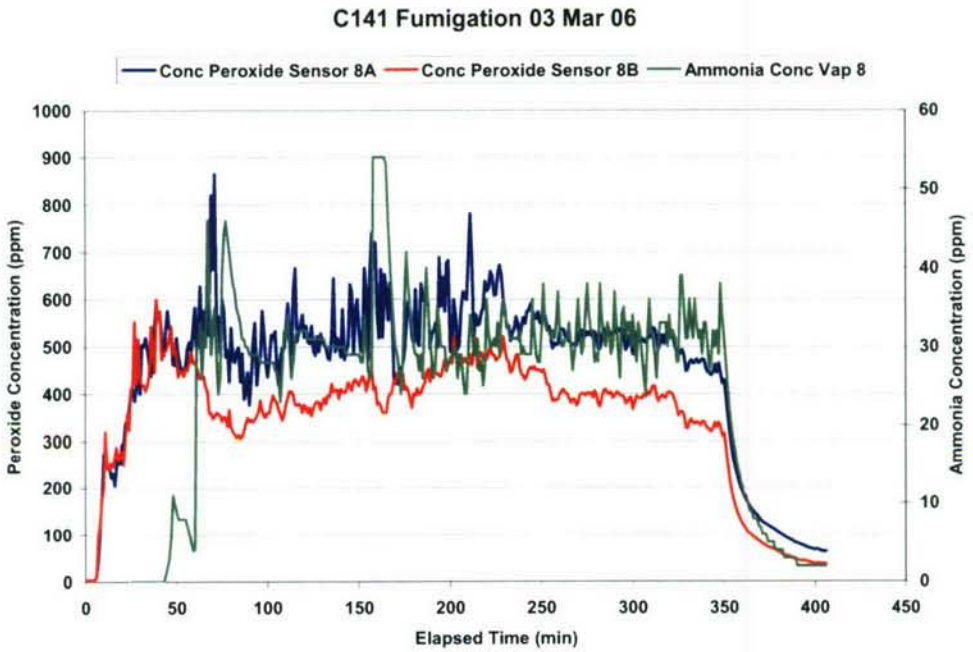


FIGURE B.4.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

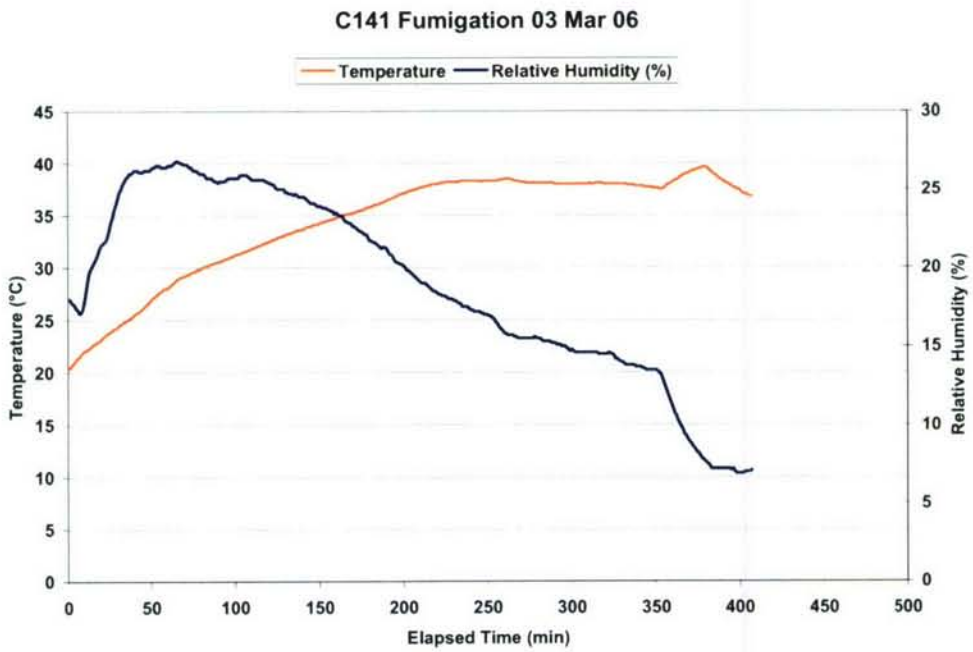


FIGURE B.4.8.2 WAS SENSOR 8, TEMP AND RH

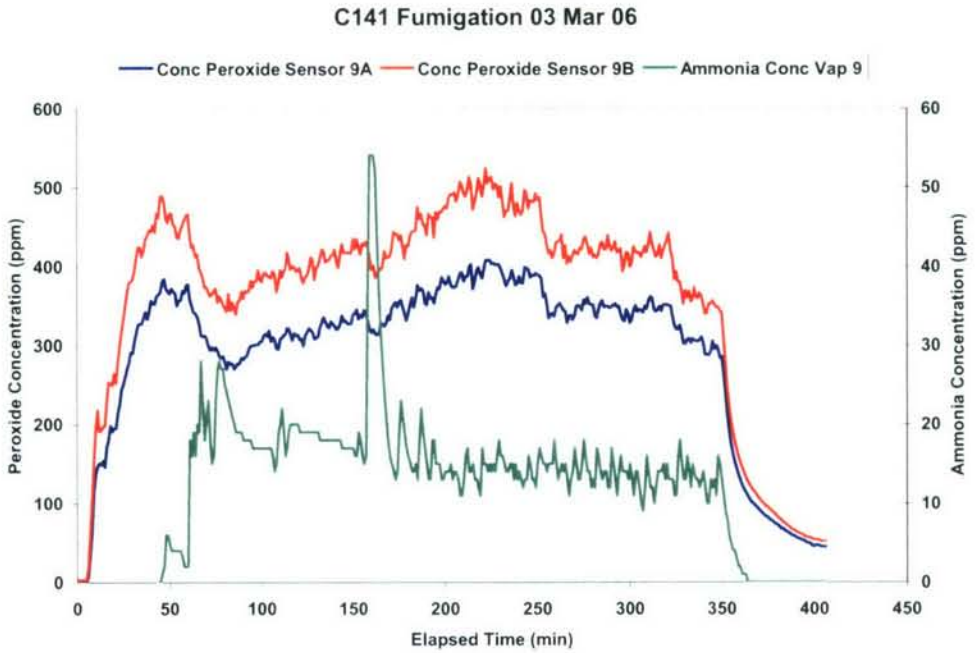


FIGURE B.4.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

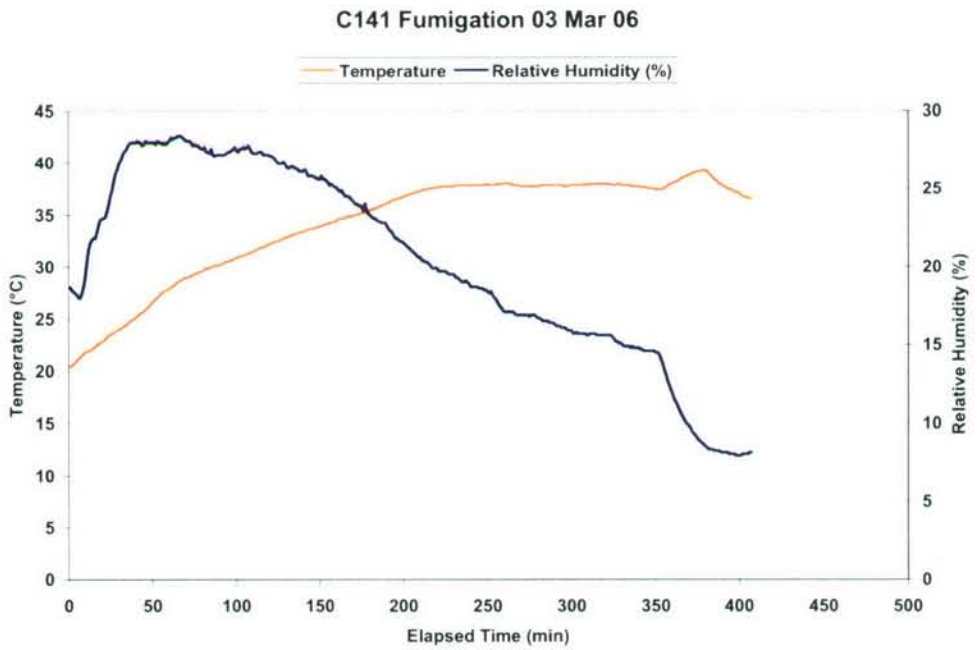


FIGURE B.4.9.2 WAS SENSOR 9, TEMP AND RH

B.5 Control Charts for 7 March 2006

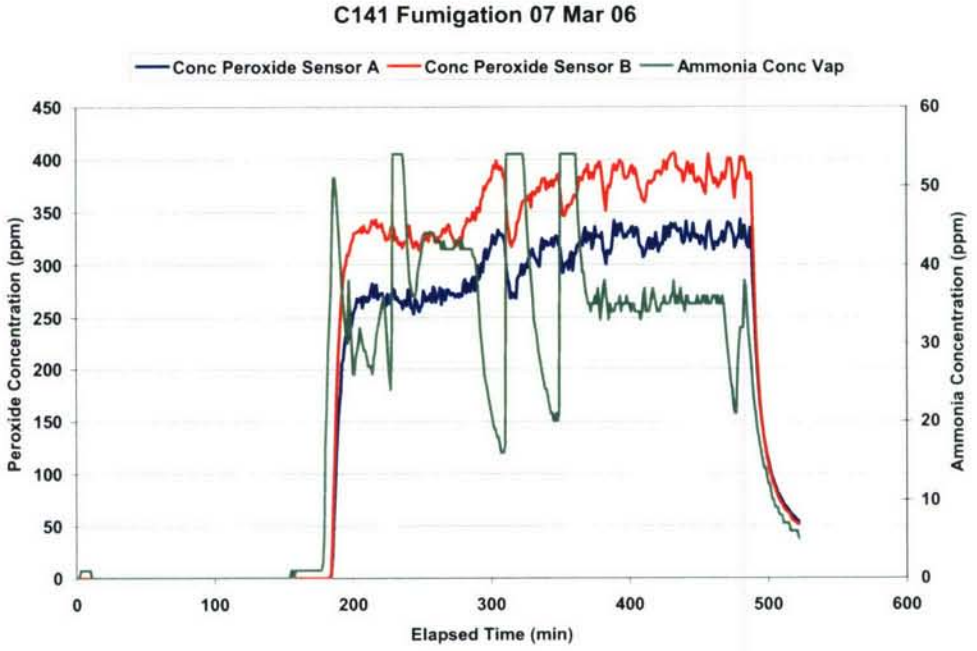


FIGURE B.5.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

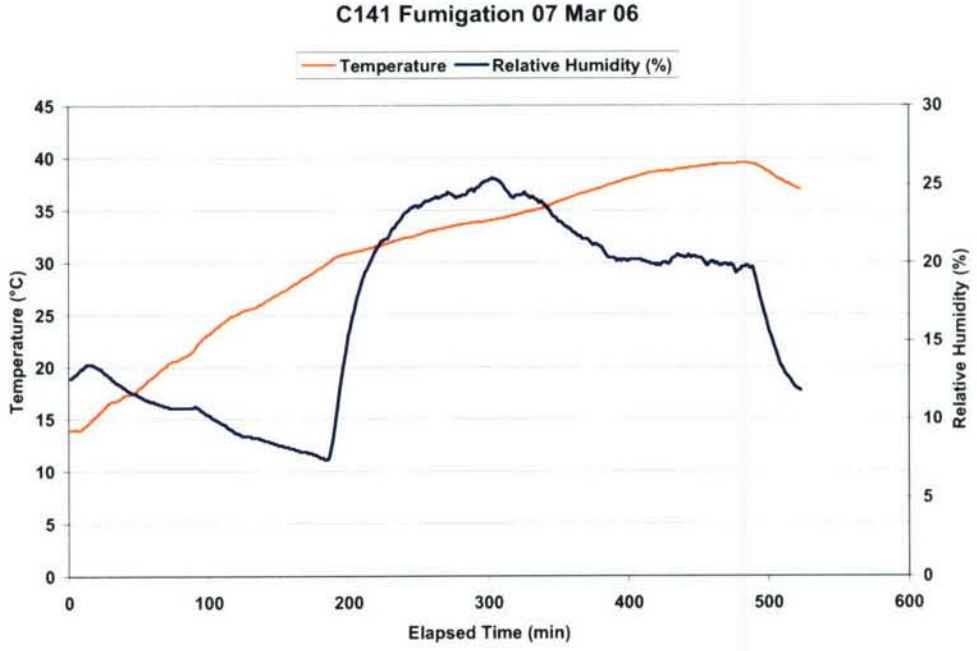


FIGURE B.5.1.2 WAS SENSOR 1, TEMP AND RH

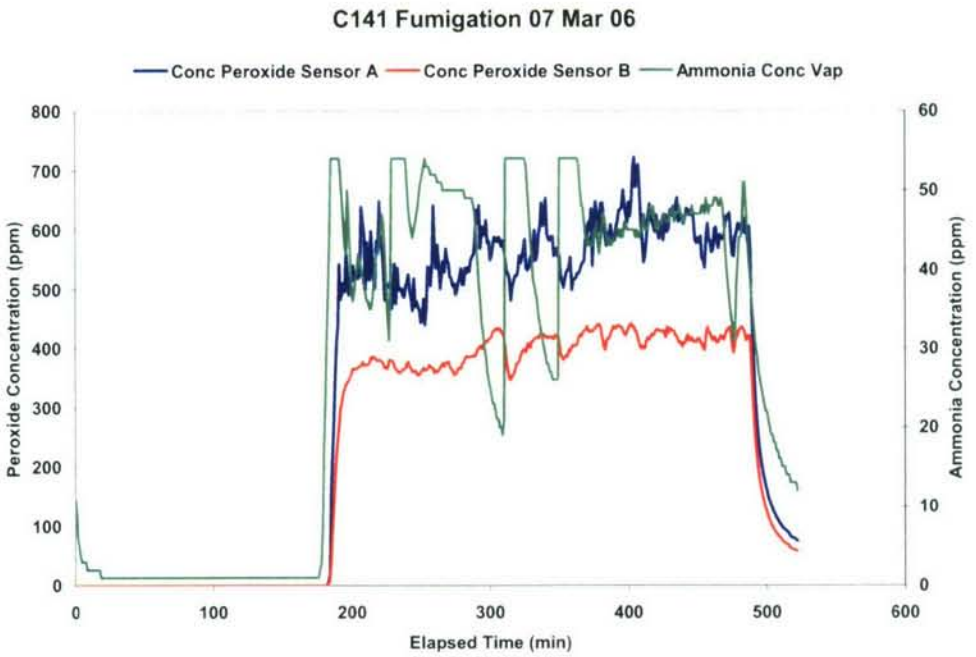


FIGURE B.5.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

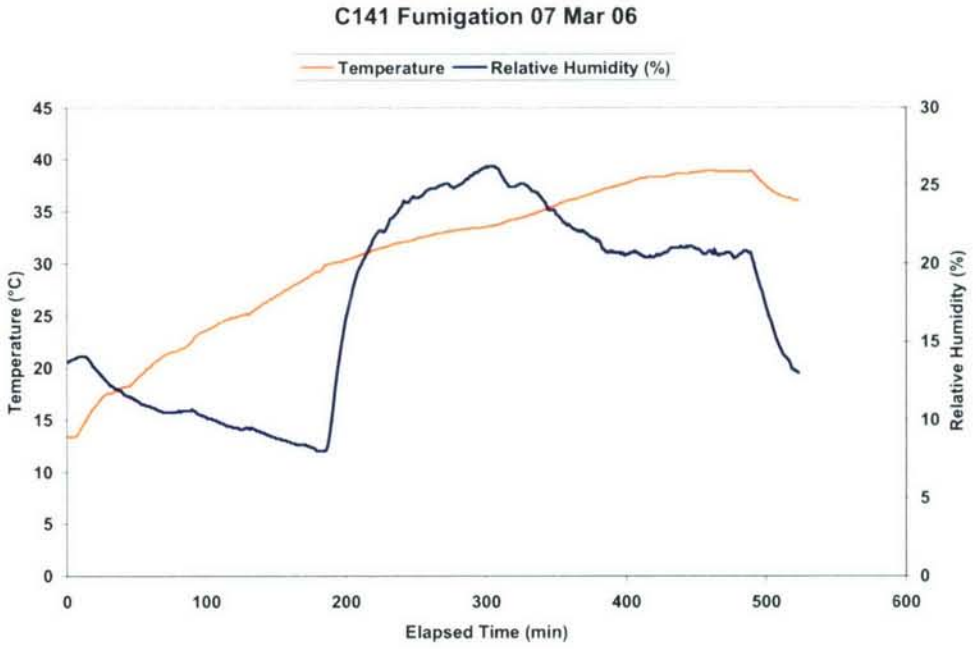


FIGURE B.5.2.2 WAS SENSOR 2, TEMP AND RH

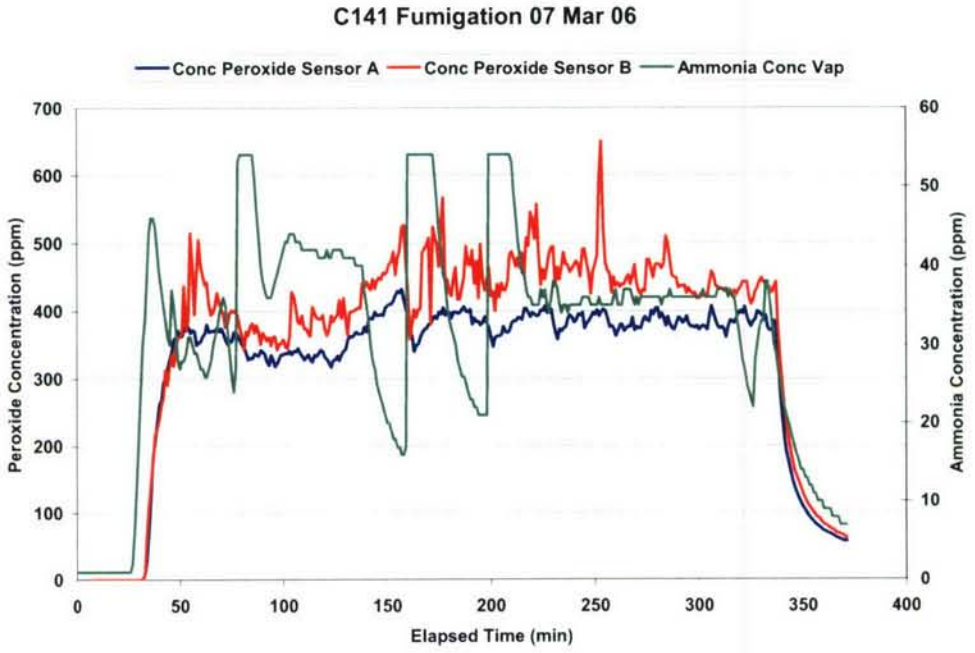


FIGURE B.5.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

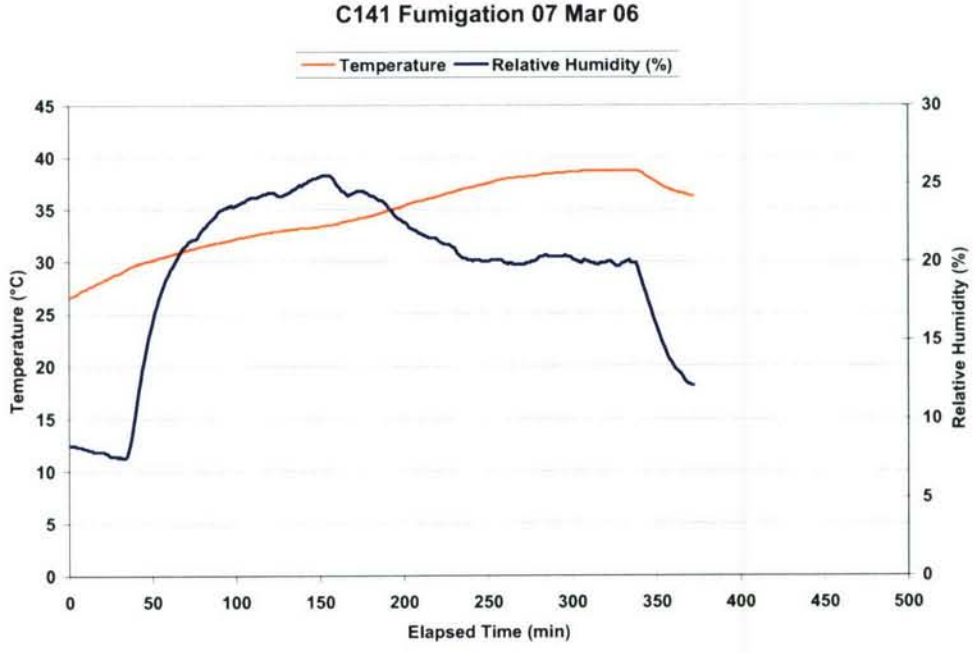


FIGURE B.5.3.2 WAS SENSOR 3, TEMP AND RH

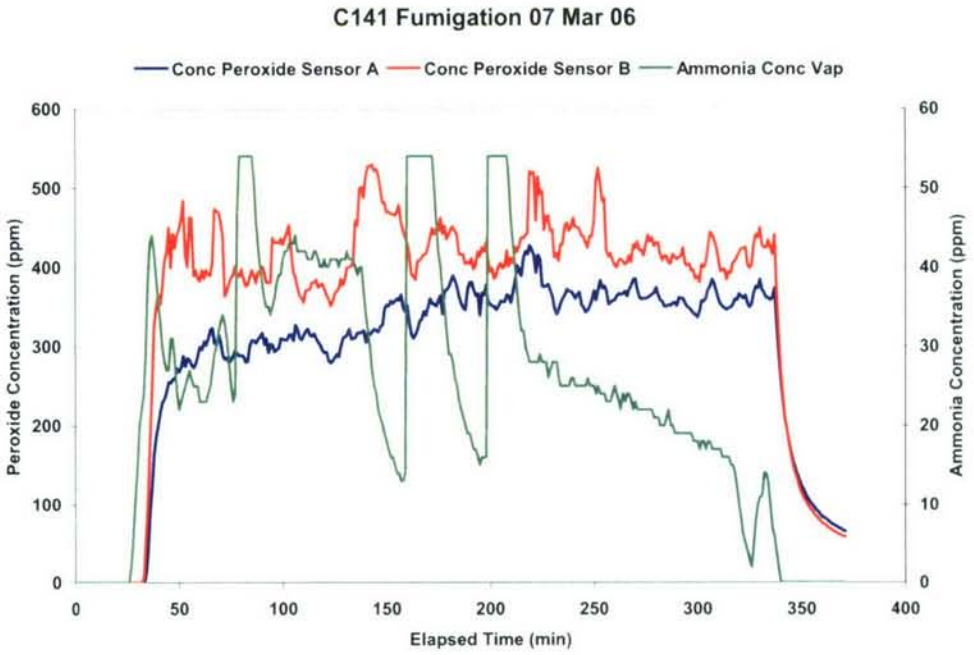


FIGURE B.5.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

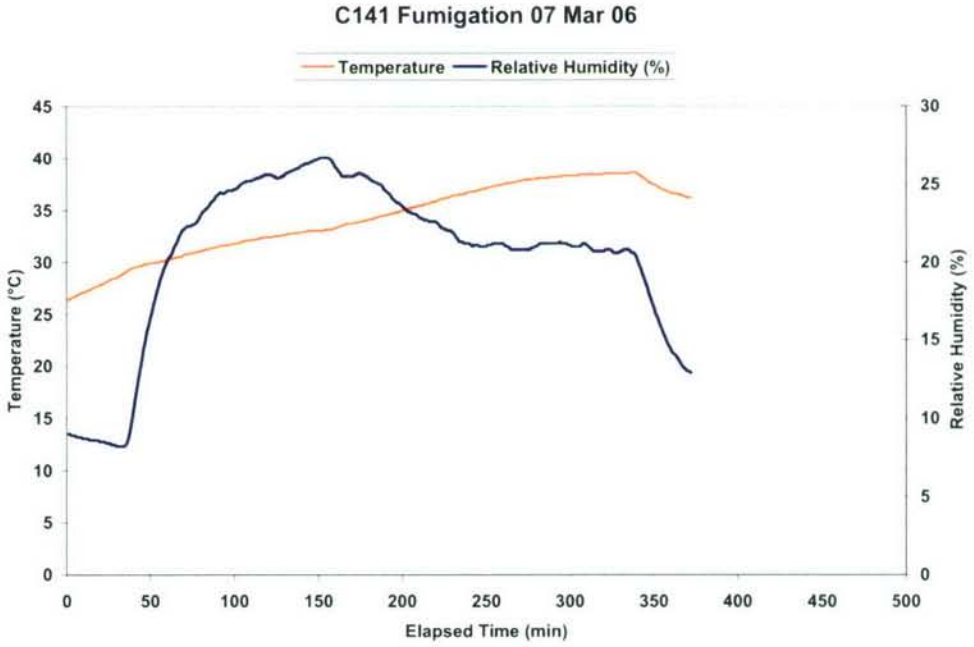


FIGURE B.5.4.2 WAS SENSOR 4, TEMP AND RH

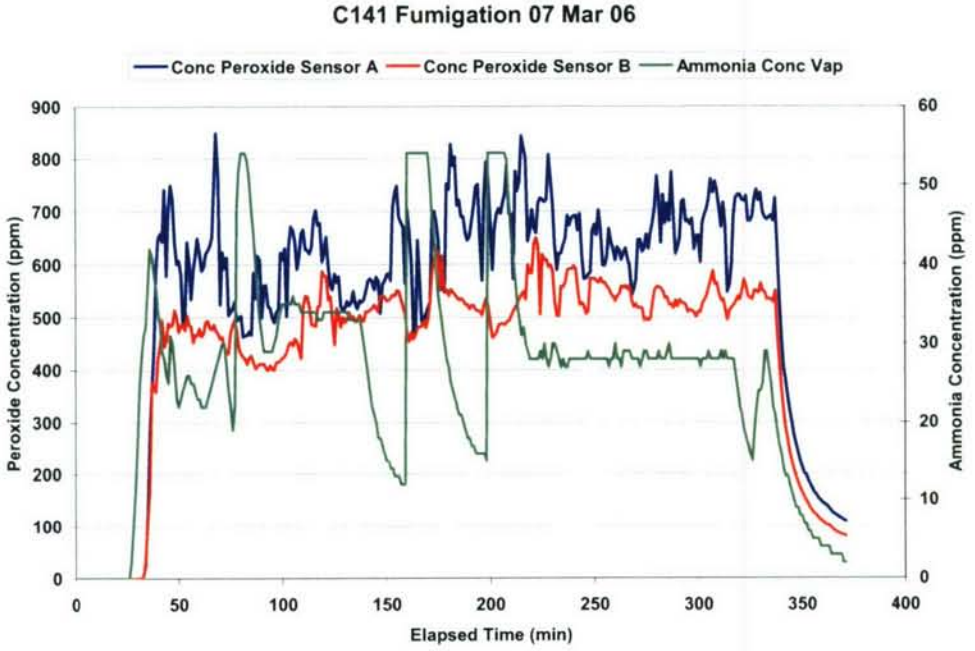


FIGURE B.5.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

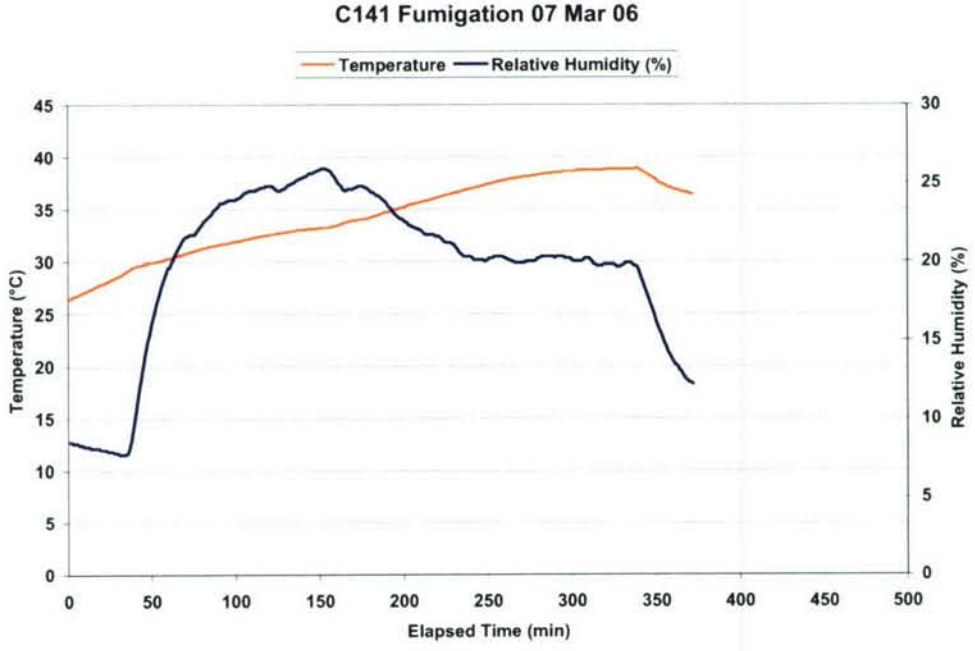


FIGURE B.5.5.2 WAS SENSOR 5, TEMP AND RH

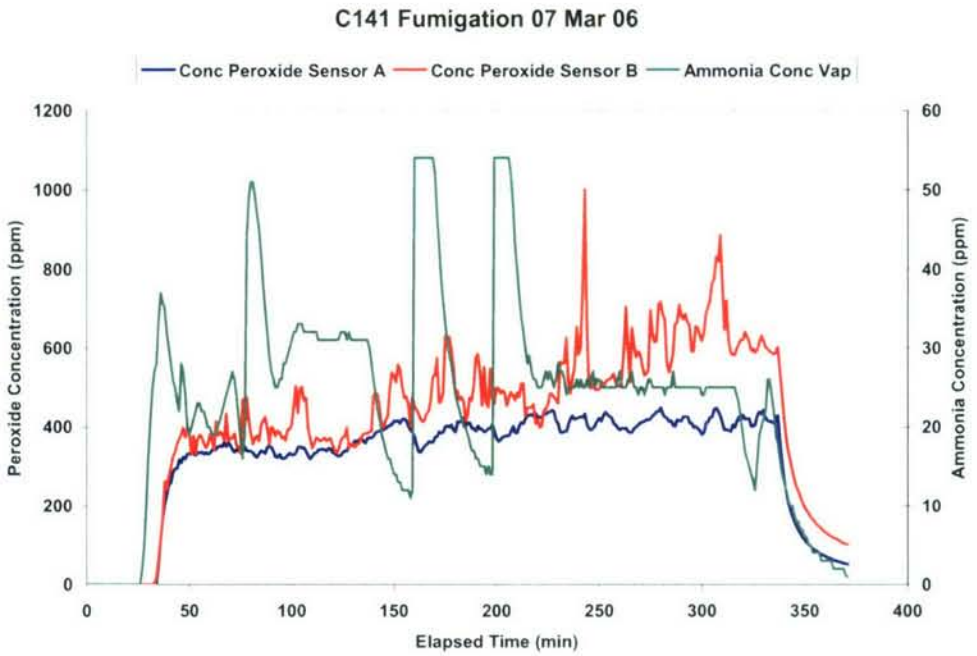


FIGURE B.5.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

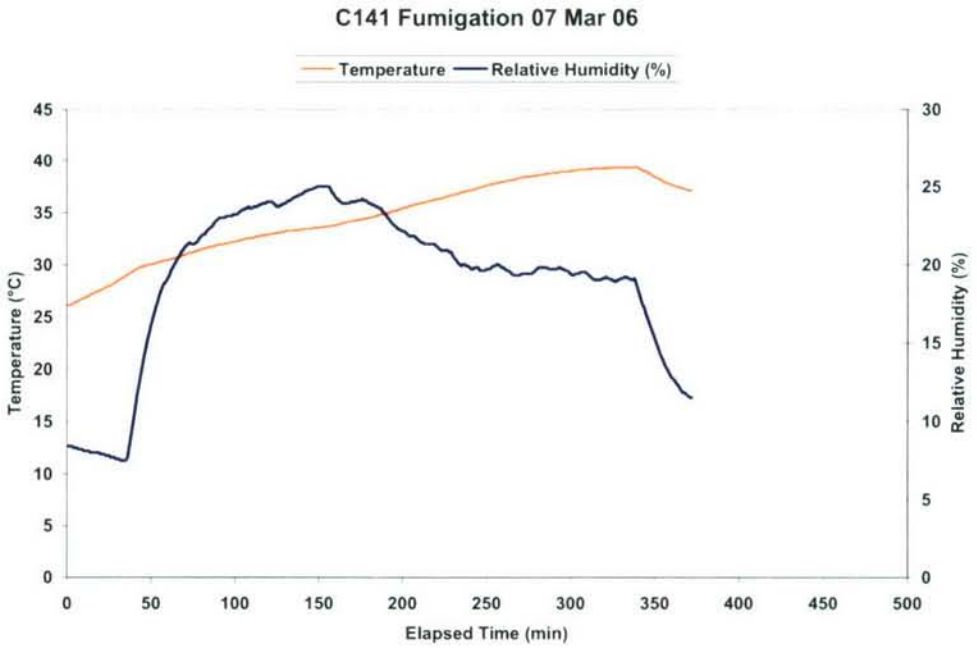


FIGURE B.5.6.2 WAS SENSOR 6, TEMP AND RH

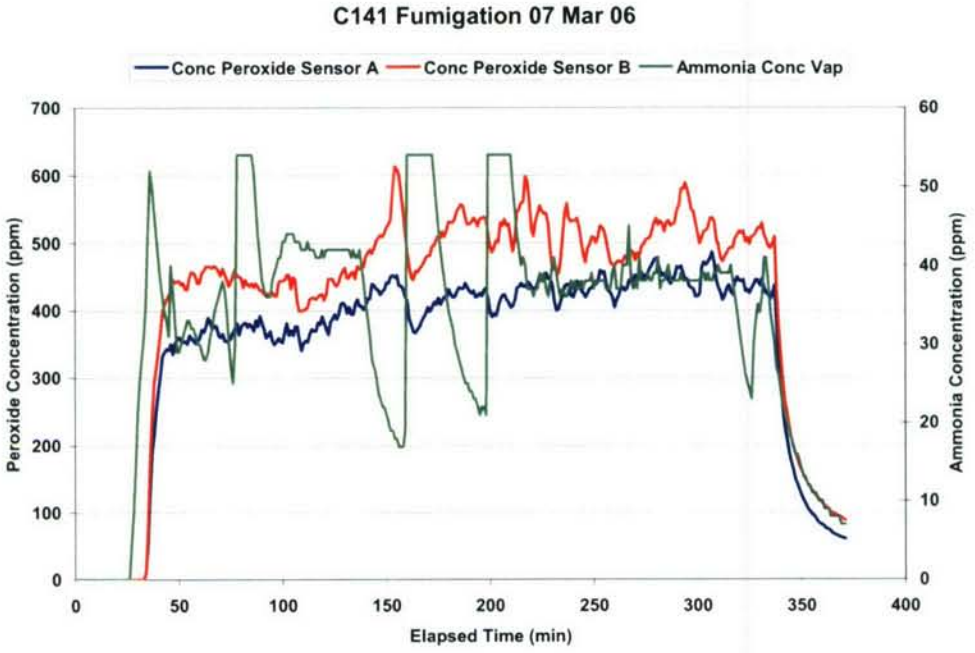


FIGURE B.5.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

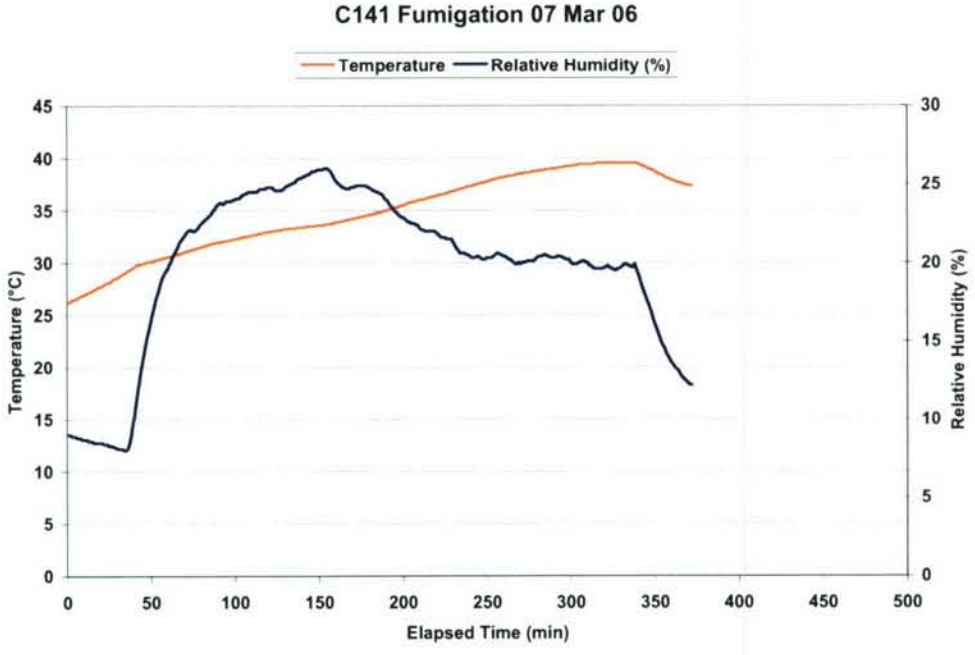


FIGURE B.5.7.2 WAS SENSOR 7, TEMP AND RH

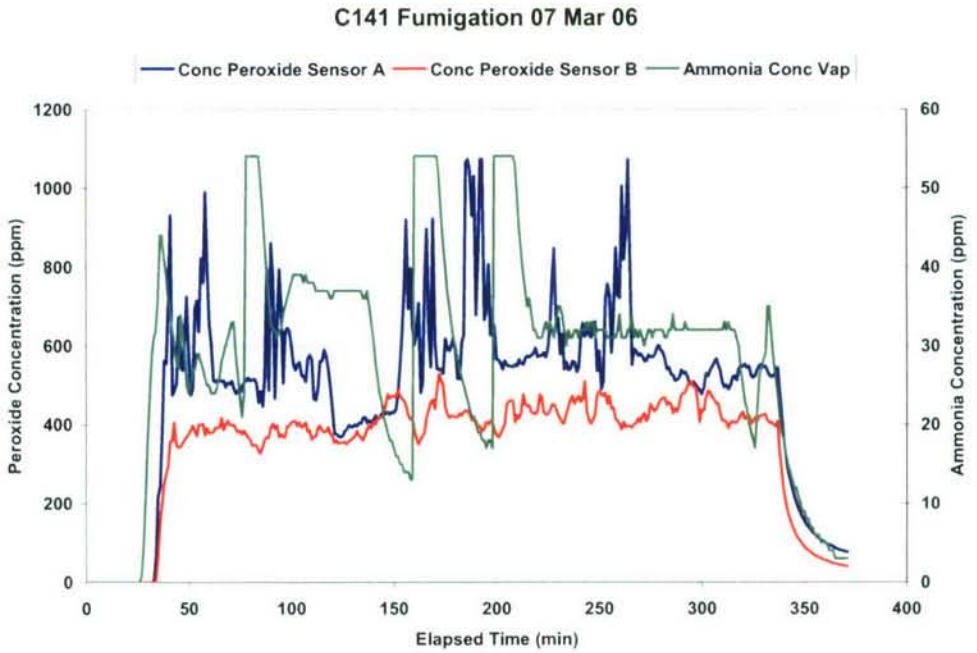


FIGURE B.5.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

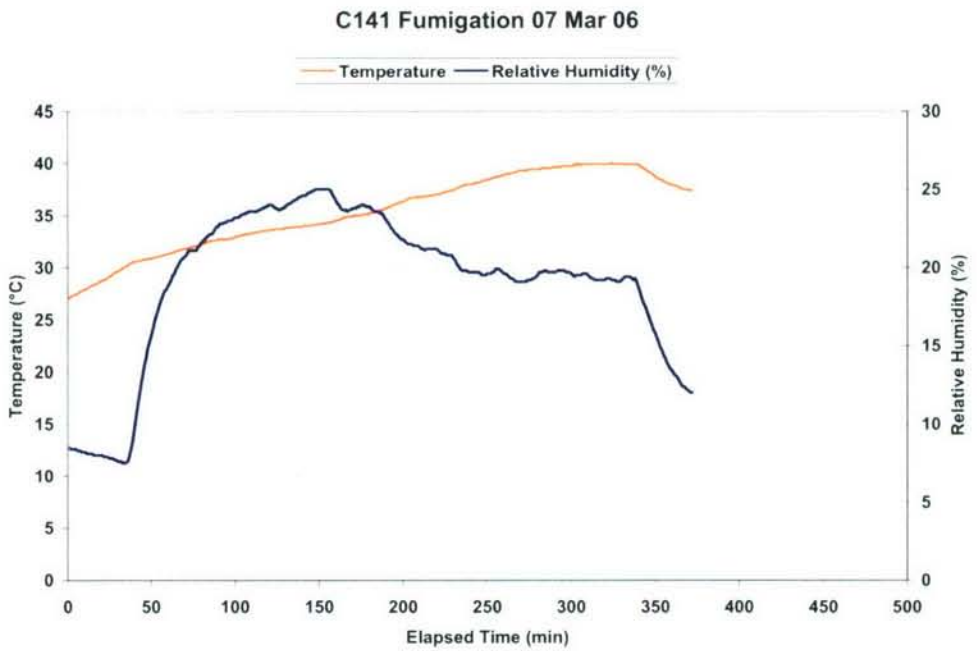


FIGURE B.5.8.2 WAS SENSOR 8, TEMP AND RH

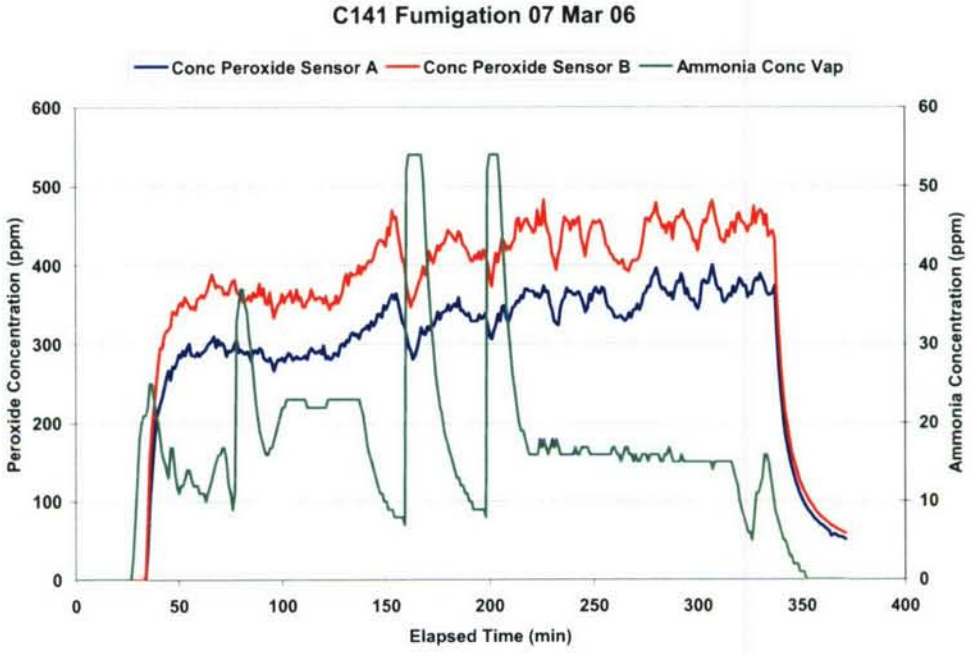


FIGURE B.5.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

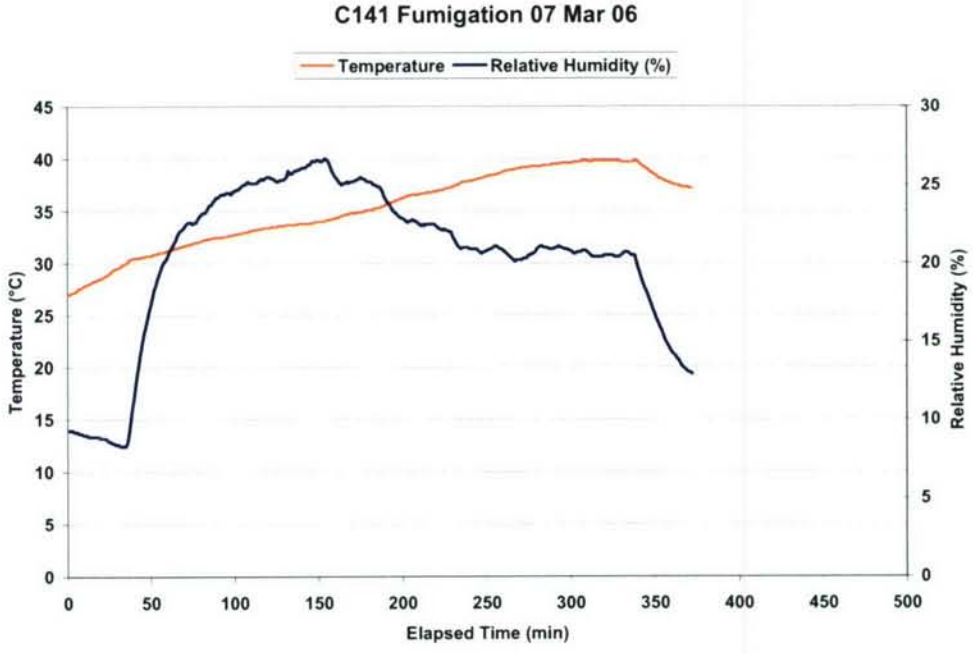


FIGURE B.5.9.2 WAS SENSOR 9, TEMP AND RH

B.6 Control Charts for 8 March 2006

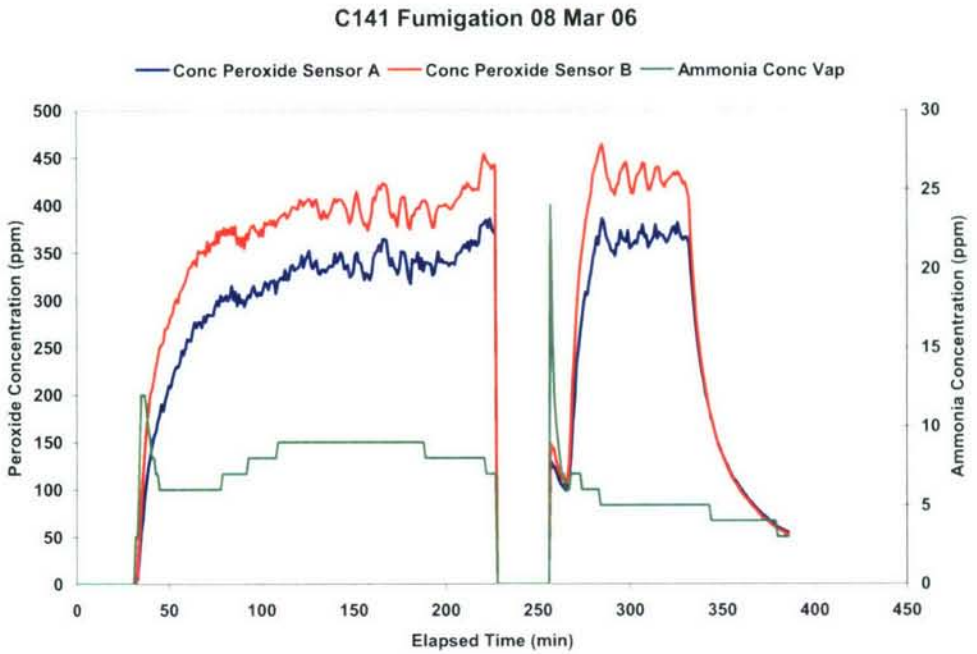


FIGURE B.6.1.1 WAS SENSOR 1, hydrogen peroxide AND ammonia

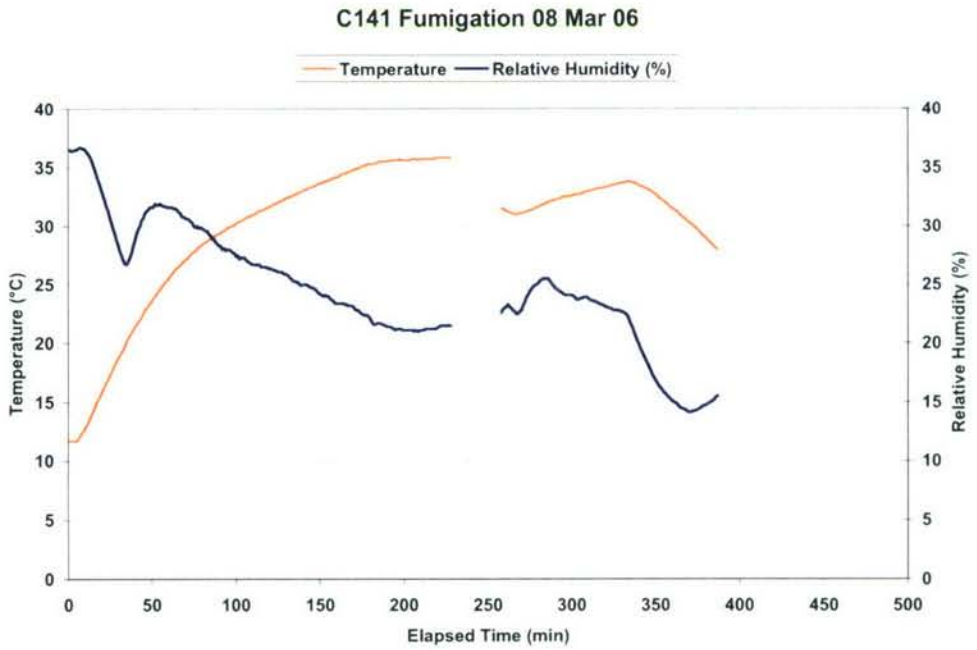


FIGURE B.6.1.2 WAS SENSOR 1, TEMP AND RH

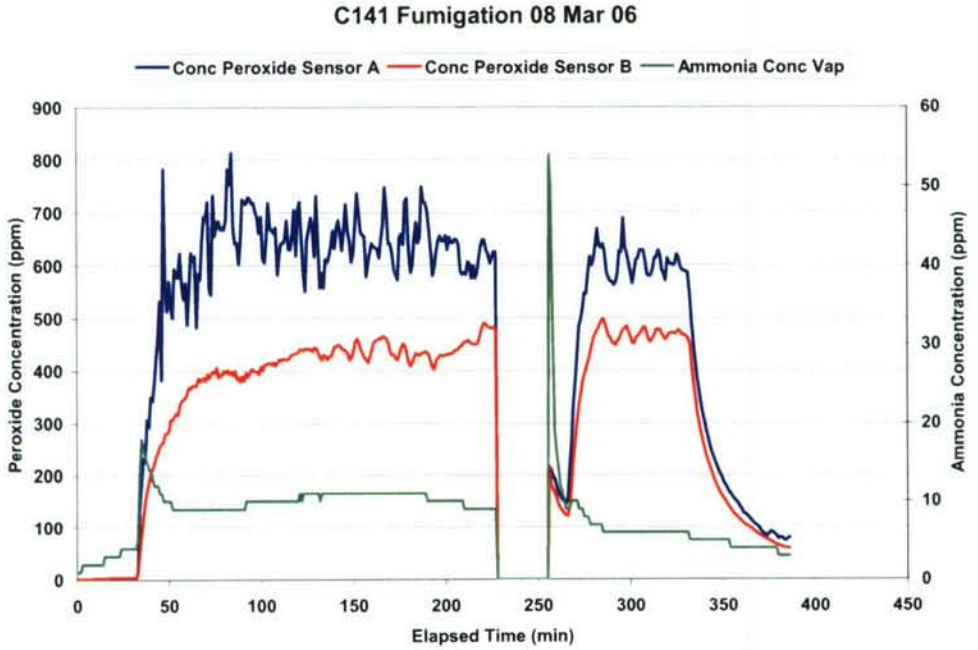


FIGURE B.6.2.1 WAS SENSOR 2, hydrogen peroxide AND ammonia

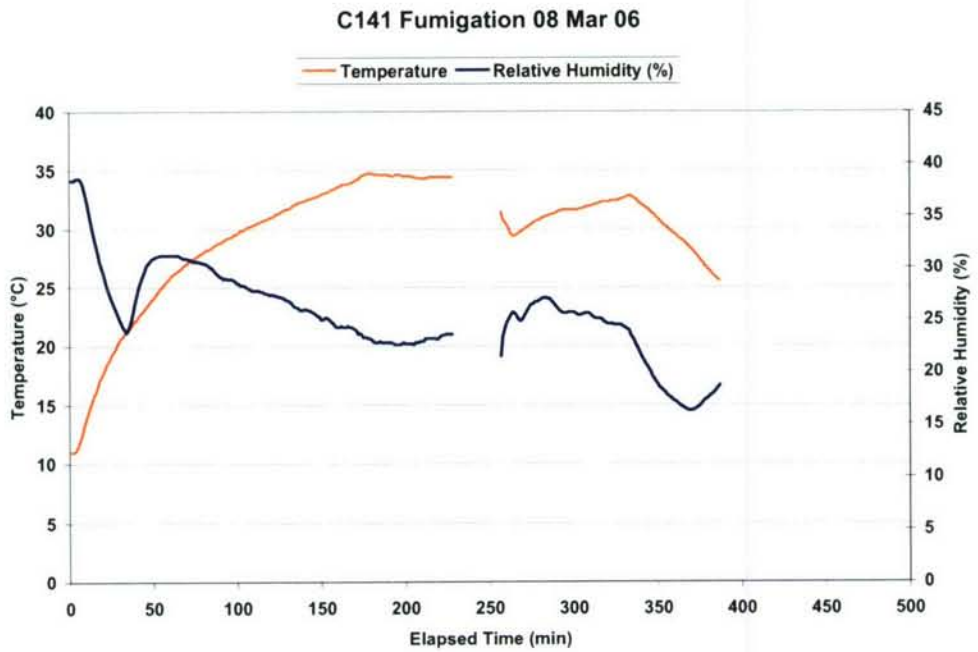


FIGURE B.6.2.2 WAS SENSOR 2, TEMP AND RH

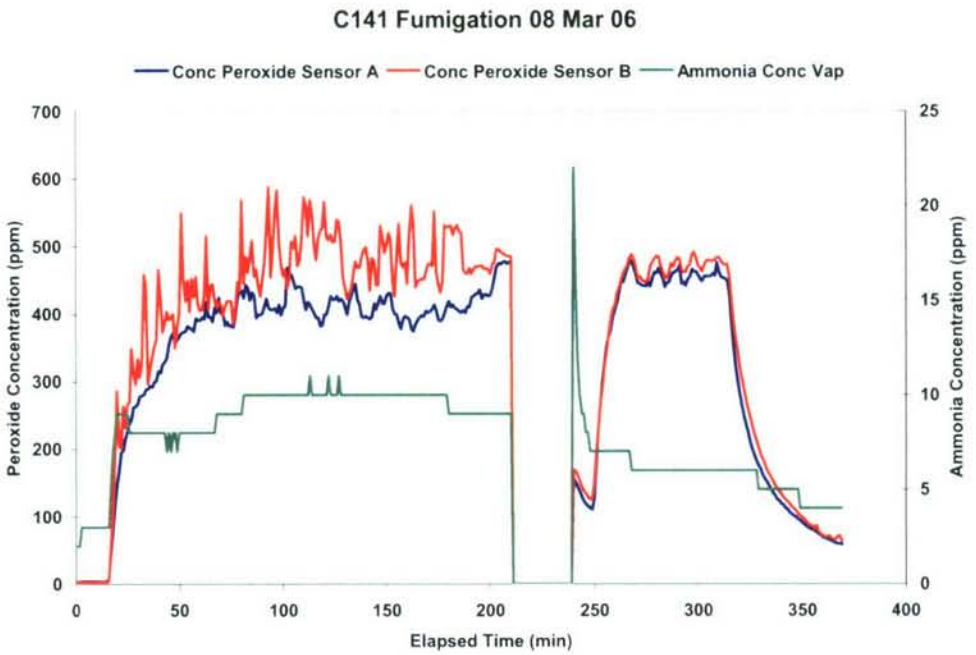


FIGURE B.6.3.1 WAS SENSOR 3, hydrogen peroxide AND ammonia

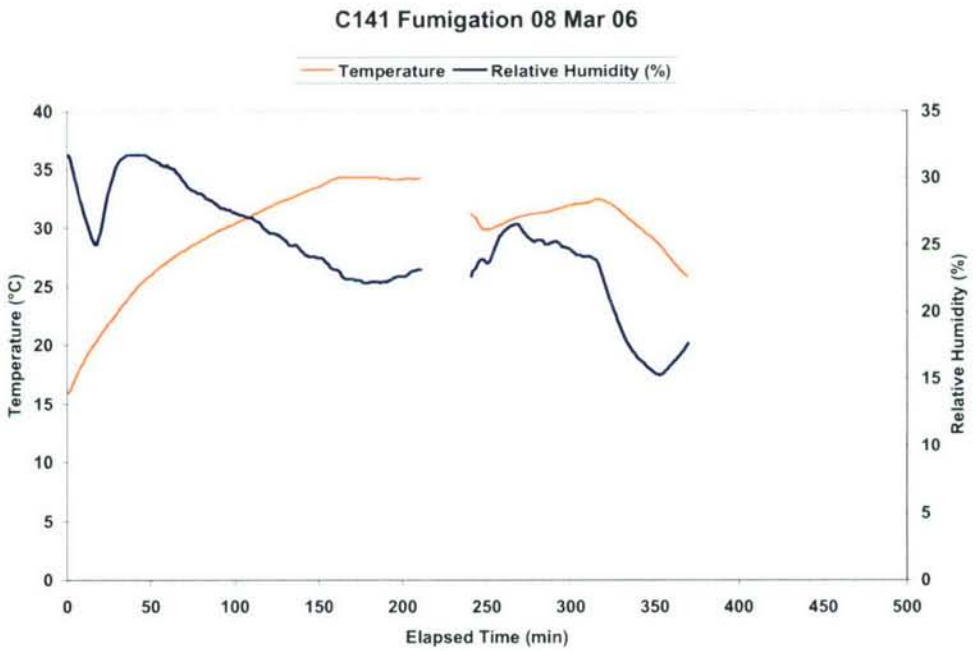


FIGURE B.6.3.2 WAS SENSOR 3, TEMP AND RH

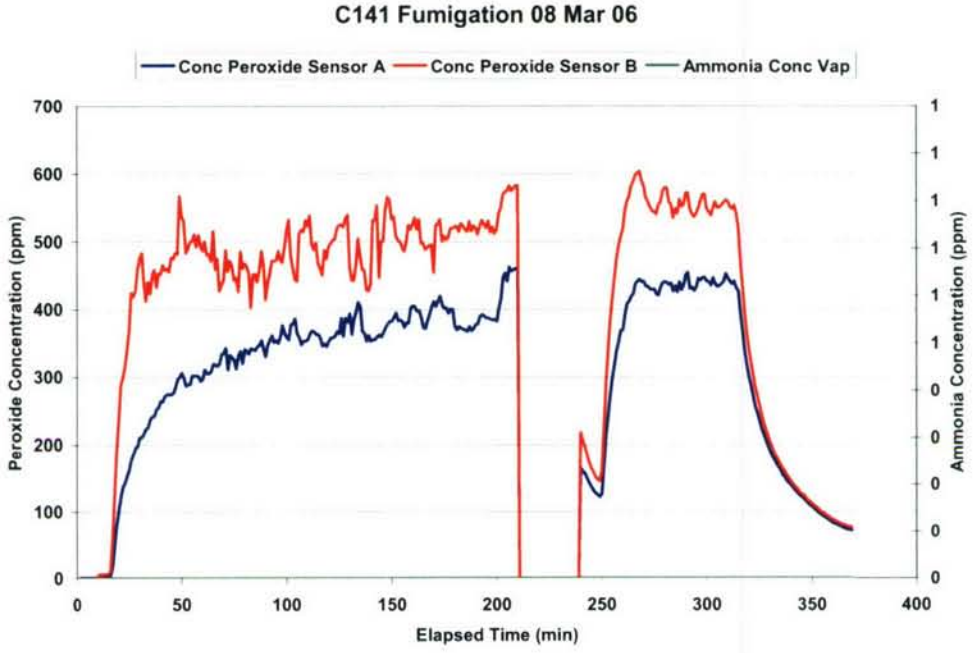


FIGURE B.6.4.1 WAS SENSOR 4, hydrogen peroxide AND ammonia

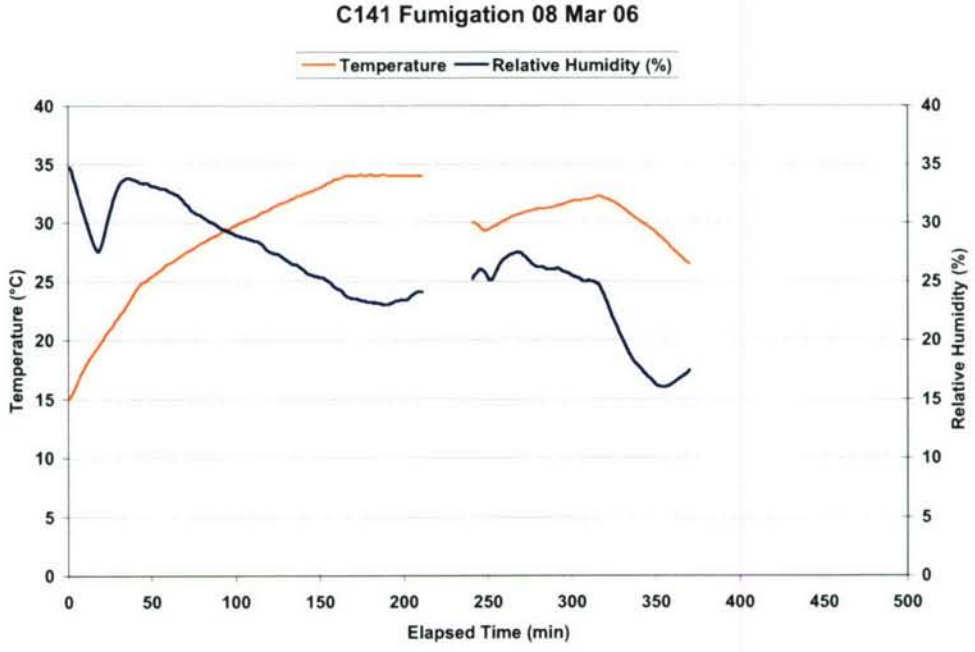


FIGURE B.6.4.2 WAS SENSOR 4, TEMP AND RH

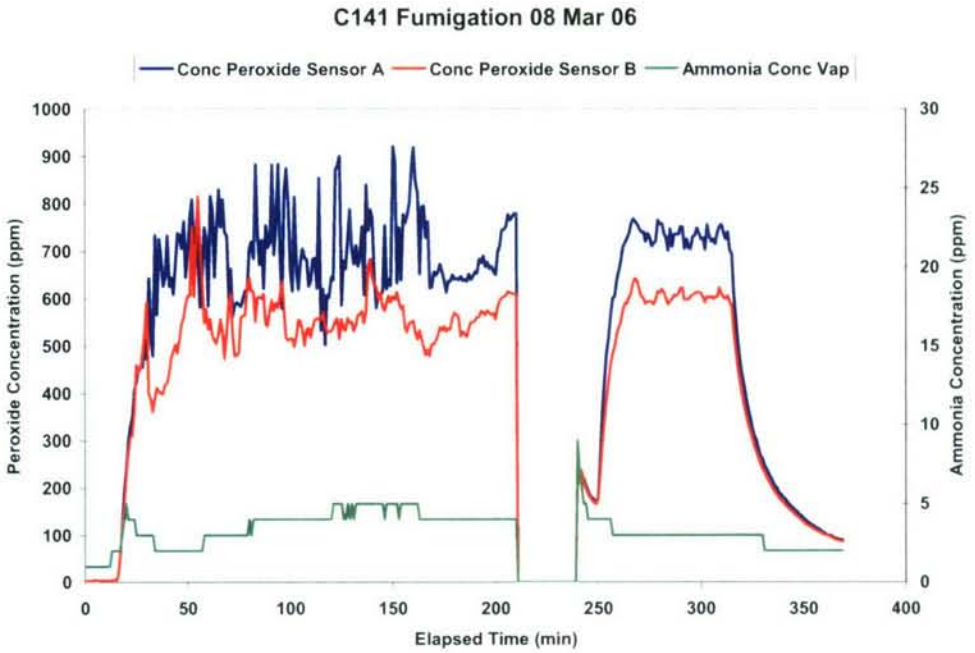


FIGURE B.6.5.1 WAS SENSOR 5, hydrogen peroxide AND ammonia

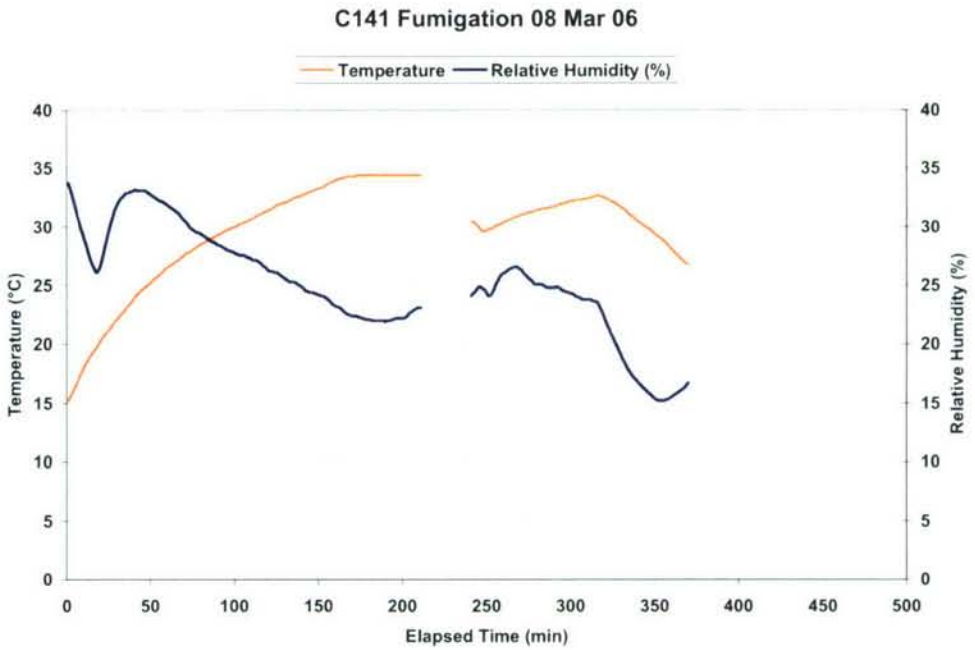


FIGURE B.6.5.2 WAS SENSOR 5, TEMP AND RH

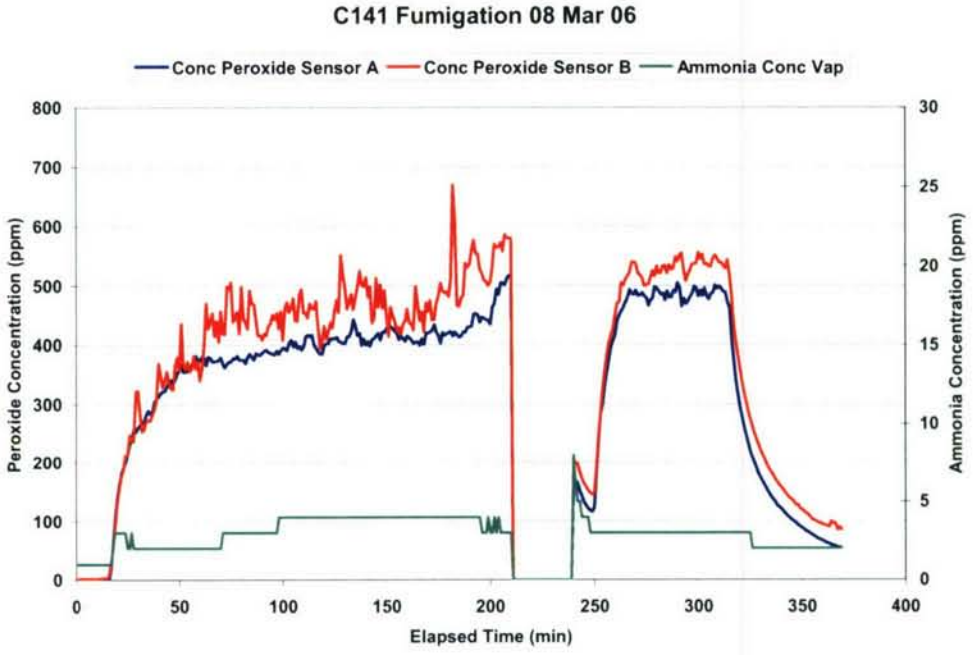


FIGURE B.6.6.1 WAS SENSOR 6, hydrogen peroxide AND ammonia

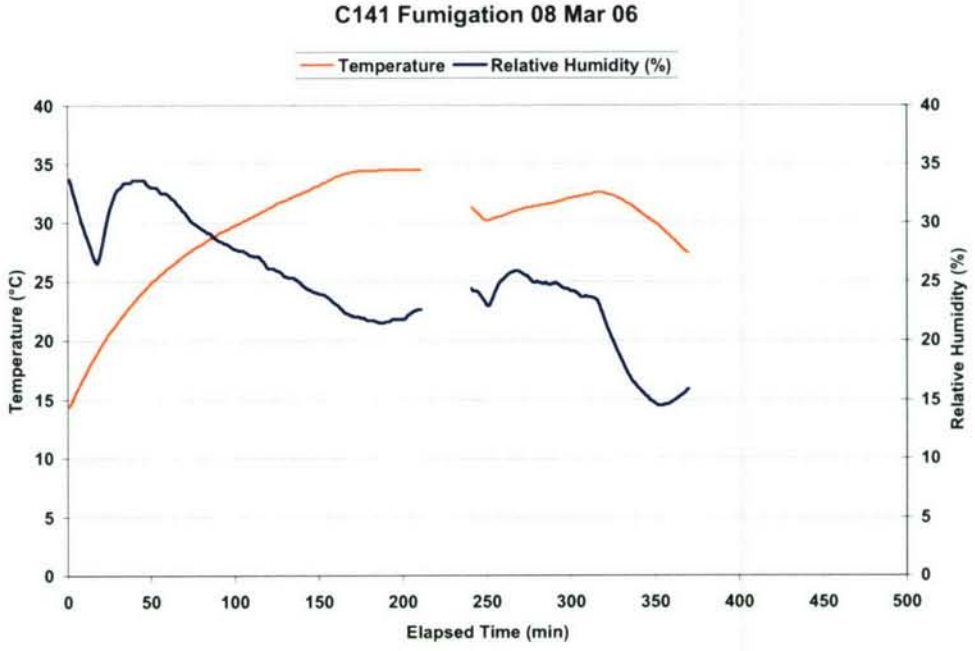


FIGURE B.6.6.2 WAS SENSOR 6, TEMP AND RH

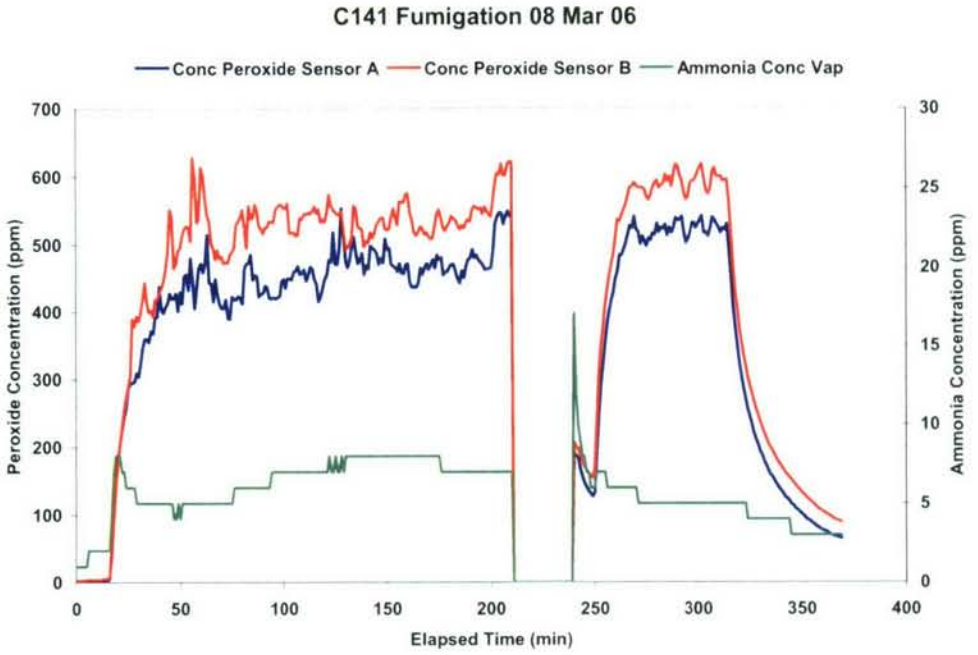


FIGURE B.6.7.1 WAS SENSOR 7, hydrogen peroxide AND ammonia

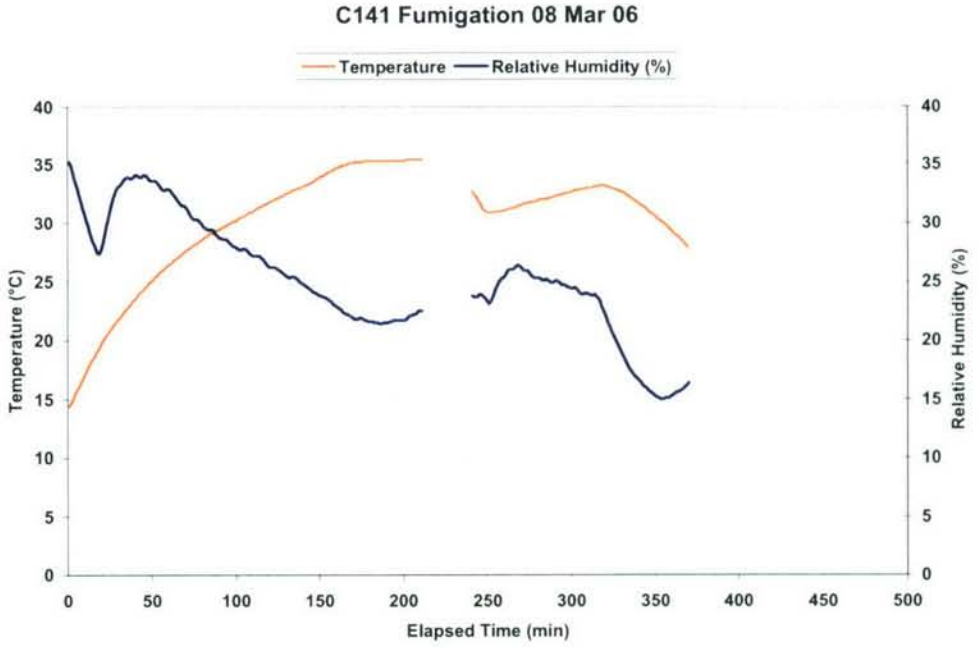


FIGURE B.6.7.2 WAS SENSOR 7, TEMP AND RH

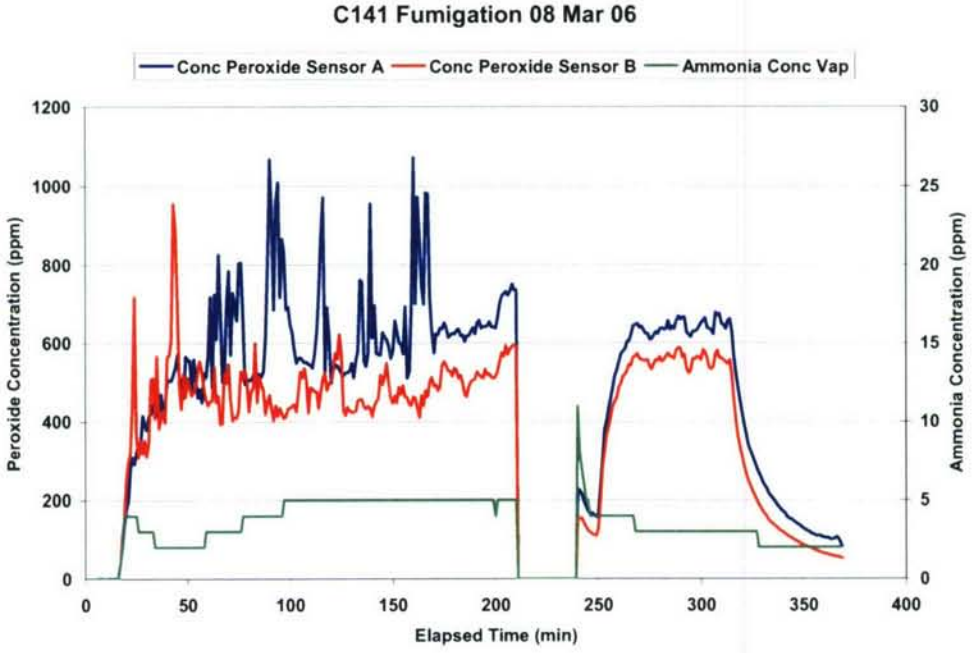


FIGURE B.6.8.1 WAS SENSOR 8, hydrogen peroxide AND ammonia

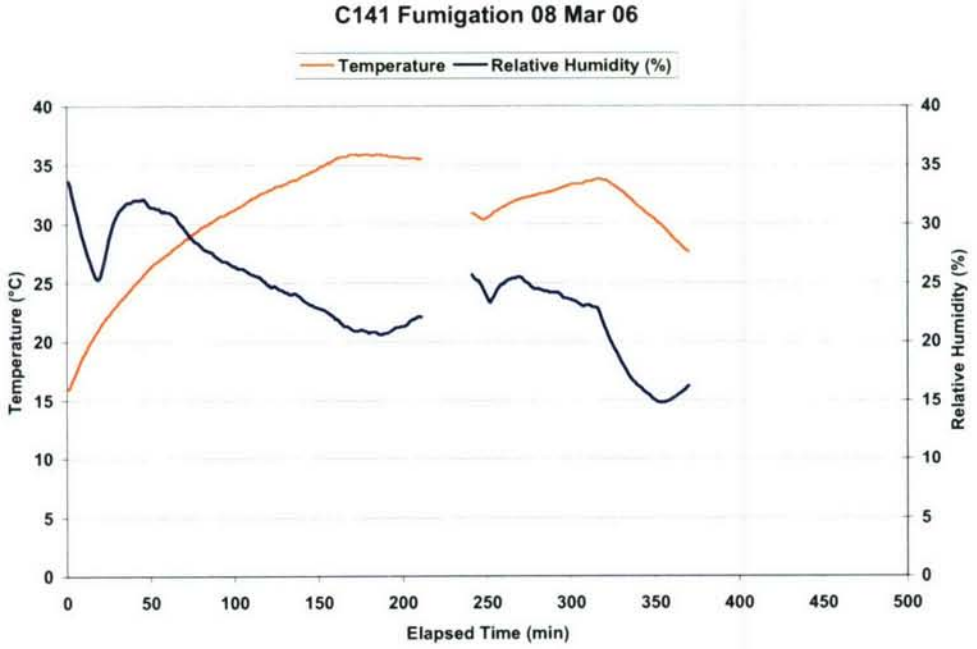


FIGURE B.6.8.2 WAS SENSOR 8, TEMP AND RH

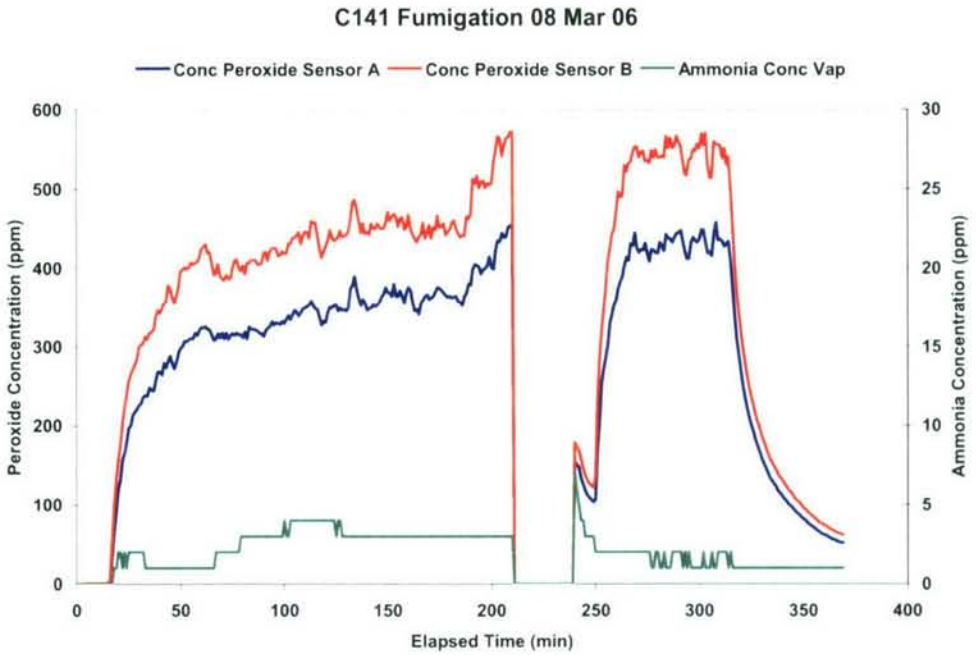


FIGURE B.6.9.1 WAS SENSOR 9, hydrogen peroxide AND ammonia

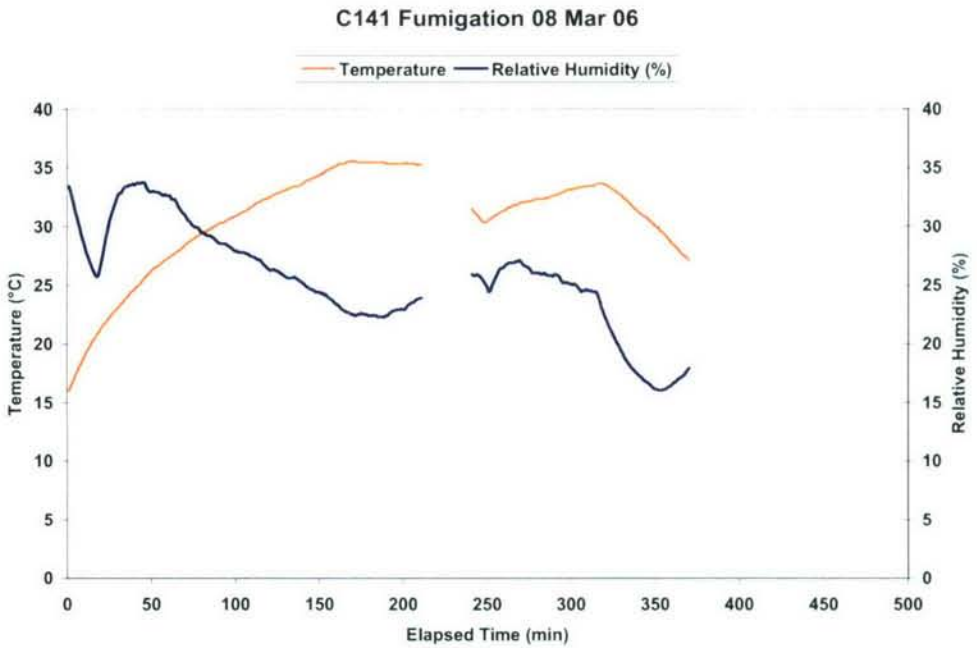


FIGURE B.6.9.2 WAS SENSOR 9, TEMP AND RH